## Number 4

## PRACTICAL SUGGESTIONS *for* TEACHING

**HOLLIS L. CASWELL** *Editor*

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# SCIENCE EXPERIENCES *for* ELEMENTARY SCHOOLS

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PRACTICAL SUGGESTIONS FOR TEACHING

*Edited by* HOLLIS L. CASWELL

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# SCIENCE EXPERIENCES FOR ELEMENTARY SCHOOLS

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# *Editor's Introduction*

In the modern curriculum science rightfully enjoys a prominent place. Its myriad applications to our daily living require increasing understanding of scientific principles and processes. Boys and girls of elementary school age have a natural curiosity and interest in their environment, in learning why the wind blows, why some rocks are smooth and others rough, whether certain insects are friends or enemies of man, why sunshine striking an aquarium is broken into colors, how airplanes fly. These interests provide a basis for significant child experiences involving science. As children have opportunity to engage in such experiences, they begin to learn something of the scientific method and to understand some of the basic scientific principles.

The broadened emphasis on science in the elementary school necessarily requires that children have firsthand experience in the solution of science problems challenging to their interests. Yet many teachers have found it difficult to discover suitable experiments for children of elementary school age; others have been handicapped by the lack of what they consider essential equipment; and still others have been reluctant to undertake science instruction because they felt that their own background of science knowledge was inadequate.

This monograph suggests simple, practical, interesting projects and experiments for classroom teachers to work out with their pupils. The experiments illustrate fundamental scientific principles, but nevertheless are within the range of understanding of elementary school children. The explanations and the diagrams are explicit and detailed so that teachers may use them as presented or adapt them to the needs of particular situations. The author suggests a wide use of materials from the child's environment and a minimum amount of basic, inexpensive equipment.

The content has been developed over a considerable period of time. Tested with many groups of pupils and of teachers in training, the experiments have been refined on the basis of actual experience. The materials presented here, designed to be used on a selective basis, should be stimulating for all elementary school workers.

HOLLIS L. CASWELL, *Dean*

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# *Preface*

There is no substitute in education for firsthand experience. Particularly is this true in the case of science education. It is logical, therefore, that an important type of activity in science in the elementary school should be experimentation.

Most of the science in most elementary schools will be taught by the regular classroom teachers. Therefore it is desirable to acquaint them with some of the experiences with science materials which are suitable for children, and with a number of experiences which may enlarge their own background of science understanding.

To give prospective elementary school teachers and teachers in service the opportunity to work at firsthand with the materials of science, a laboratory, under the direction of Professor Gerald S. Craig and Mr. Warren W. McSpadden, was established at Teachers College, Columbia University. As experiments were collected and evolved through the work of this laboratory, there developed a need for more written material to guide the work of the students. As a result, the author prepared mimeographed material covering some of the more basic experiences in certain fields of science. Eventually this material developed to a point where it was believed that it would be of value to a larger group of teachers than those who happened to be students in the Elementary School Science Laboratory; hence its publication in book form.

This book is like a cookbook in the sense that it is a collection of recipes for handling materials. It attempts to list for teachers some of the science experiences for children and tells how to go about helping the children to have them. The art of the classroom teacher consists in part in being aware of when a science activity can contribute to the growth of understanding in the child. That art this book does not attempt to teach.

To educators interested in promoting the extension of science teaching in elementary schools, the problem of apparatus is one which requires painful, not to say prayerful, thought. Certainly, an elementary school science program which requires elaborate apparatus of the high school or college type places on itself an unnecessary handicap. The major part of the equipment used in teaching science in the elementary school ought to come from the child's own environment. Most of the experiments suggested in this book can be performed with equipment obtained from the home, the schoolroom, or the local stores. There are, however, a few experiments which require equipment not readily obtained in this manner. Where such equipment is first mentioned, a footnote is appended, giving its approximate price, with a suggestion about obtaining it. Substitutes are suggested where possible. At the end of the book is given a short list of the addresses of scientific supply houses. The local high school science teacher may be able to give other addresses which will be more convenient for teachers in a given locality.

C. K. A.

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# SCIENCE EXPERIENCES
# FOR
# ELEMENTARY SCHOOLS

# CHAPTER I

# *Experiments With Plants*

This chapter is intended to suggest a number of experiences with plants which children may have indoors under the guidance of a teacher limited as to funds, specialized knowledge, and free time.

The basic meanings or integrating themes of the chapter are three: the ways in which plants are adapted to their environment; the variety of adaptations which plants have made; and the interrelationships of plants with one another and with other parts of their environment. These themes are brought out by a consideration of the conditions necessary for plant growth, by some experiences with plant structure, by experiences with food-making by plants (photosynthesis), and by experiences with the substances given off by plants. One experiment (No. 22) is concerned with the fact that plants are composed largely of water and carbon in chemical combination. Since soil is such an important part of the plant's environment, some experiences with soil have been included. These may be used if the teacher so desires to lead into a study of the forces at work on the earth or into a study of soil erosion and soil conservation.

### 1. Seeds sprout under certain conditions

It is frequently necessary to obtain seedlings for various experiments. The following methods will be found useful.

(*a*) Fold a paper towel or two or cut a piece of blotting paper to fit into shallow cake pans. Moisten with water, but do not have excess water in the pan. Count out 50 to 100 seeds of corn, peas, squash, lentils, or other plants. Place the seeds somewhat evenly on the paper and cover them with another moistened towel. Cover each pan with glass or stack the pans together, leaving a little space for ventilation. Place the pans out of direct sunlight. The seeds should sprout in a few days. It is necessary to keep the paper moist but not wet. Seeds may also be sprouted in a box of sand which is kept moist.

(*b*) A layer of moist Sphagnum moss is an excellent medium for sprouting seeds since it does not dry out quickly.

(*c*) Children should try to sprout some seeds without water, in order to learn that water is necessary for seed germination and plant growth.

After the seeds have sprouted, examine them. Are there some that did not sprout? If so, refer to Experiment 2. If some are moldy, refer to Experiment 25. Do the roots and shoots appear to come from the same part of the seed? Do they come from the same place in all seeds of the same kind of plant? Of different kinds of plants? These growing seedlings should be saved for use in later experiments.

### 2. Plants produce many more seeds than can survive

(*a*) Count the number of seeds in one row of an ear of corn. Count the number of rows and multiply. How many seeds in one ear of corn? How many ears on one corn stalk? Try to estimate the seeds on one head of a dandelion—in a milkweed pod. Count the number of seeds in one pod of a hollyhock. Count the number of pods on a stalk and of stalks on a plant. Count the seeds in one squash, one cucumber, or one tomato. Any plant will do for this activity.

(*b*) Count out 100 seeds of any kind. Germinate them, using one of the two methods suggested in Experiment 1. Do they all germinate? What percentage of them? Wild seeds show more striking results than seeds from a seed store because commercial seeds are especially selected to germinate well.

### 3. Roots turn down, shoots turn up

It is of great importance to the plant that roots should always strike into the earth and shoots should always push up into the air and sun. The following experiment proves that this action takes place.

Secure two glass plates of the same size and a piece of blotting paper the same size as the glass. Wet the blotter thoroughly and lay it on a glass plate. A few drops of carbolic acid added to the water will help discourage mold. Arrange on the blotter some lentil, corn, pea, squash, watermelon, pumpkin, or other fairly large seeds. Be sure that the seeds are not all pointing the same way. Place the other glass plate over the seeds. Hold the glasses tightly in the fingers and have another person tie them together, using plenty of string. Do not use rubber bands, as the sharp edges of the glass cut them. Stand the glasses on edge in a pan containing about ½ inch of water. After the seeds sprout, notice that no matter which way the seeds were placed, the shoots turn up and the roots turn down. When the roots are an inch or so long, turn the glass plates so that some other edge is in the water. Notice what happens to the roots and the shoots in a day or two.

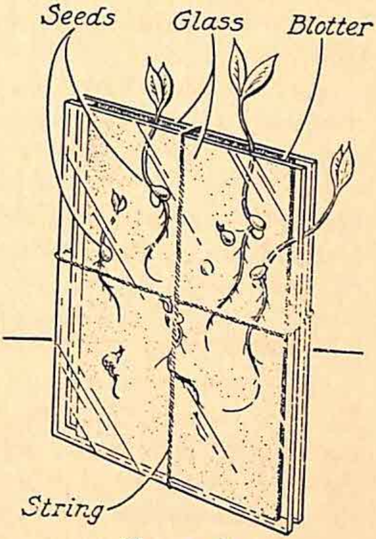

FIGURE 1

Two other facts usually are made evident by this experiment. One is that the seeds which were either the wettest or the driest do not sprout as well as those which were neither too wet nor too dry. The other is that if the plants grow long enough, they eventually die because of lack of soil to supply them with needed material for growth. To prove this latter fact, transplant the seedlings from some of the suggested experiments to soil and try to grow the rest in glass.

### 4. Plants get water and food through their root hairs

Examine a young root in a glass plate "garden" under the binocular microscope[1] or under a hand lens. Notice the tiny hair-like structures on the root. These are root hairs, and it is through these that the plant gets its water and dissolved food substances from the soil. Examine several different kinds of plants. Corn roots are especially good for this experiment. Plants wilt after they have been transplanted because the delicate root hairs have been broken off in the process.

---

[1] A microscope is not necessary, and in inexperienced hands may even be undesirable. If one can be obtained, a binocular dissecting microscope is the type preferred by the author, because children can see through it readily. A good 3-inch hand lens may be bought at an optician's or from a scientific supply house for about $2.00 or less. A "tripod magnifier," more powerful, will cost about 90 cents.

### 5. Growth takes place at the tips of the roots and the shoots

Select from among the seedlings which have been sprouted in connection with Experiment 1 or 3 a few with roots about 1 inch long. With a fine pen and India ink make dots ⅛ inch apart on both root and shoot. Take great care not to injure the plant. Allow the plants to continue to grow. In two or three days examine to see which marks have grown farther apart. Results will differ with different plants.

### 6. Seeds must be planted at the proper depth

Make a glass-sided box about 7 inches high, 16 inches long, and 1 inch wide (called a germination box). Place about 1 inch of soil in the bottom, then arrange on the soil and next to the glass a few seeds each of corn, beans, peas, tomato, lentil, squash, or other plants. Add another inch of soil, then more seeds, and so on until the box is full. Water lightly. Observe the seeds every day or two. Notice that some seeds grow best at particular depths of planting. A large jar may be used instead of the box.

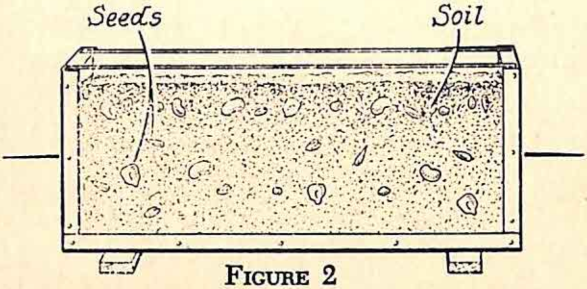

FIGURE 2

### 7. Seeds require different times for sprouting

Take a large flower pot, a window box, or seed flat. Fill it with soil and plant in it a few seeds of each of several kinds of plants. Plant to a uniform depth of 1 inch. Notice how long it takes for different kinds of plants to appear. Repeat this experiment to see if the results are consistent.

### 8. Seeds do not grow well when too crowded

Plant in a medium-sized flower pot a very large number of corn, bean, or pea seeds. Have an actual layer of seeds in the earth. Note result of overcrowding as the plants grow.

**9. Roots seek water**

(*a*) Sloping boxes with wire mesh bottoms should be constructed. The wire should be about ¼ inch mesh. Place a thin layer of wet Sphagnum moss on the bottom to cover the wire. On this layer of moss plant some assorted seeds; then cover them with 1½ inches or more of wet moss. This should be sprinkled daily. After the plants begin to appear, examine the wire bottom closely. Many roots, which have gone downward under the influence of gravity in the wet moss, will probably turn when they commence to emerge into the dry air and will start back into the moss. This often results in the death of the root.

(*b*) For this experiment boxes about 14 inches square and 5 inches deep, with glass fronts, are needed. Take two 4-inch flower pots. Stopper the drainage hole in each tightly. Place one pot close to the glass in one corner of the box. Place the other in the diagonally opposite corner. Fill the box with earth, working it around each flower pot. Plant a number of seeds very close to the glass, working them down with your finger. Plant other seeds at various other places in the earth. Fill *one* of the flower pots with water. Leave the other empty. The empty pot is for a control. Do not put any water directly on the soil. The only source of water the plants have is that which comes through the porous flower pot. After the plants have grown a while, it can probably be noticed that the course of the roots which can be seen through

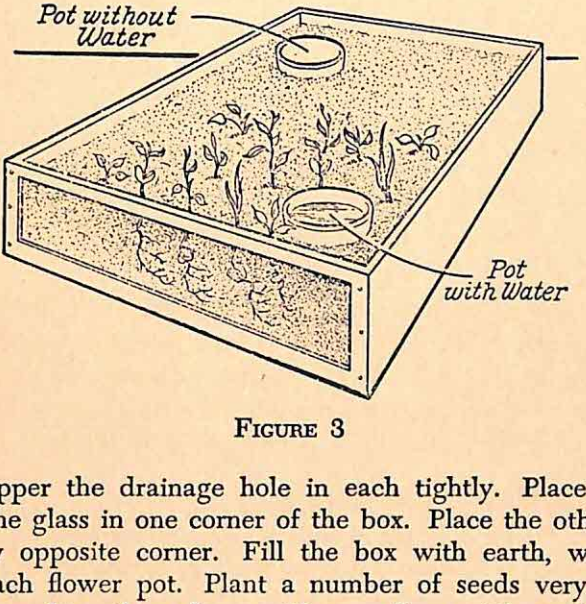

FIGURE 3

but practically none will get to the two other sections. Notice the sprouting and subsequent growth of the seeds. The plants in wet sand will often grow much faster than those in soil but later they fall behind. Why? Why is there little or no growth in dry sand or dry soil?

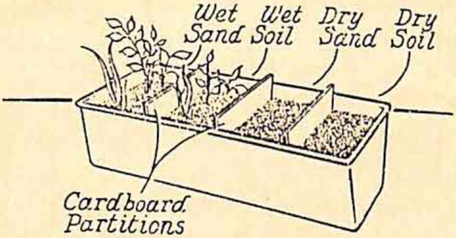

FIGURE 6

### 15. Green plants make starch when in sunshine

Before doing this experiment it is necessary that children know that when placed on material containing starch, iodine will turn blue. This is the chemist's test for iodine. The first part of this experiment is to show this test.

To 3 tablespoons of water, add about 15 drops of tincture of iodine. Note the color of the solution. Put a few drops of this solution on a bit of corn starch, a white potato, a cracker, or a piece of bread. Notice the blue color which should appear.

Remove a young green leaf from a plant which is growing in sunshine. Drop the leaf into boiling water one or two minutes to kill it. Put about 2 tablespoons of alcohol into a small tin cup.[2] Place this cup in water in a larger cup or pot, to give the effect of a double boiler. Heat the alcohol by boiling the water. (One should never attempt to heat alcohol directly over a flame because of the danger of fire should the alcohol boil over.) Put the killed leaf into the alcohol and continue heating until the green color of the leaf has all passed out into the alcohol. (The green is chlorophyll.) Remove the whitened leaf and spread it out on a glass plate or put it in a saucer. Flood it with the iodine solution. Note if a blue or blue-black color appears. Sometimes several minutes elapse before the color becomes noticeable. As a control, repeat the experiment using a leaf from a plant which has been kept in the dark for a day or two.

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[2] Pyrex beakers are useful in place of the cups, as it is easier to see what is happening. They may be obtained from a scientific supply house at about the following prices: 100 cc. and 250 cc. sizes, 20 cents; 400 cc. size, 26 cents; 600 cc. size, 31 cents. It is suggested that each school have several of the 250 cc. and 400 cc. size and a few of the other sizes. These may be kept in some central place where they can be used by several teachers.

### 16. Plants reproduce in many ways

The ability to reproduce in several ways is of great importance to the survival of plants.

(*a*) Some plants, as has been seen, reproduce by means of seeds.

(*b*) Some plants reproduce by means of bulbs or tubers. Plant sections of a potato; each section should have two or three eyes. Potatoes will often sprout if stored in a dark place. Plant some onions. Arrange a beet in a tumbler of water so that the bottom of the beet dips slightly into the water. The beet may be held in place with toothpicks stuck into it and resting on the rim of the tumbler. In a few days the beet should start to put on new leaves and roots. Repeat this experiment with a sweet potato. Only about 1 inch of the potato should be in the water. Not all sweet potatoes will sprout. Cut off 1 or 2 inches from the top of a carrot and set the top in a finger bowl with a little water.

(*c*) Some plants reproduce by means of leaves or cuttings. Begonias and geraniums are common examples of plants which will put out roots and form a new plant if a stem of the old plant is thrust into soil or water. Grafting of trees or other plants is done on a somewhat similar principle. Pussy willows, cut in the spring and kept in water, often form new roots. So does ivy.

(*d*) Many plants reproduce in two or more ways. Although begonias and geraniums are usually started from slips or cuttings, they also produce seeds. These seeds can be bought from seed stores and raised with a little care. Potatoes sometimes form "potato balls" which are really seed pods. Onions, carrots, and beets are normally raised from seeds. Of what advantage is it to the plant to be able to reproduce in more than one way?

### 17. Plants give off oxygen in light

Place a lighted candle on a glass plate and cover it with a large glass jar such as a "battery jar."[8] Wait for the candle to go out.

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[8] A glass battery jar 6 inches in diameter and 8 inches high will cost about 80 cents in quantities of six or more.

Raise the jar slightly and insert a burning splinter of wood. The flame will go out, showing that there is not sufficient oxygen present to support combustion. This proves that a flame uses up some of the oxygen in the air.

Now remove the jar, relight the candle, place a growing plant beside it, replace the jar. Use grease to seal the crack between the plate and the jar. After the candle has removed enough oxygen so that it goes out, set the whole arrangement in the sun for one or two days. Test the air in the jar with a burning splinter. If the splinter now burns for a while, it proves that the plant has given off oxygen, since when it was first set up there was not enough oxygen left to support combustion.

There is a popular notion that plants "breathe" carbon dioxide in contrast to animals, which breathe oxygen. As a matter of fact, the plant breathes oxygen, too, but in other life processes (photosynthesis) it releases more oxygen than it uses up.

### 18. Plants give off carbon dioxide in darkness

Place a plant and a small vial or dish of limewater (calcium hydroxide solution) on a glass plate under a jar, and seal with grease. Prepare another similar (control) setup without the plant. Set both away in the dark for a day or two. If the limewater turns milky or shows a white scum, it proves that carbon dioxide is present. If a difference is found between the test jar and the control jar, what does it seem to prove? How do you account for a scum on the limewater in the jar without a plant?

### 19. Plants in sunlight give off water

Take a growing plant, such as a begonia or geranium. Secure a piece of cardboard somewhat larger than the flower pot. In the center of the cardboard punch a hole large enough for the stem of the plant. Make a scissors cut from this hole to the edge of the cardboard. The cardboard may now be placed around the stem without injuring it, as is shown in Figure 7. Close the scissors cut with Scotch tape and fill in around the stem with Plasticine so that no water can pass directly from the soil. Invert a bottle or jar of suitable size over the plant and place in sunlight. In a few hours drops of water should appear inside the glass. How did they get there? From the outside air? Directly from the soil? From the plant? What controls may be suggested for this experiment?

### 20. Shoots exert pressure upward

Plant 10 seeds of some fairly large plant (corn, beans, etc.) in a 4-inch flower pot. Water the seeds and then lay over the rim of the pot a lantern slide cover glass or other small glass plate. As the plants grow upward, what happens to the plate? How many such plates will the shoots support?

### 21. Seeds contain air

Put about 20 bean (or other) seeds in a small glass and cover them with warm water. Notice any small bubbles of air which come from the seeds. Do almost all the bubbles come at the same places on each seed? If bubbles come at other places, examine the seed to see if it is cracked. Every seed has a tiny hole through which water can enter to start the germination process.

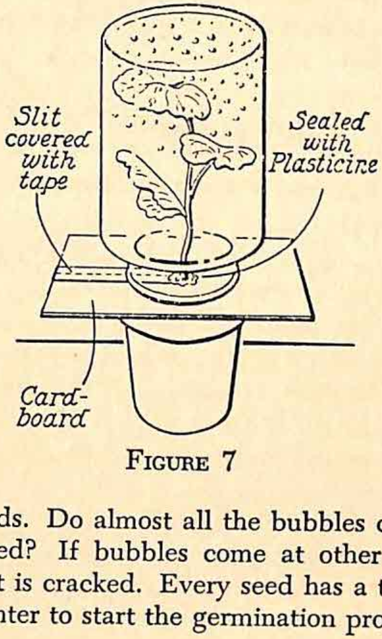


FIGURE 7

### 22. Plant and animal tissues contain water

Place some dried seeds in a test tube or small tin can. Heat over a flame, gently at first, then more strongly. Hold a cold glass plate near the mouth of the tube or can to condense any steam which may be given off. As the seeds are heated gently, water which was present in the "dry" seeds is driven out. With stronger heating the plant material itself undergoes chemical change into water and carbon.

Repeat the experiment with fresh leaves and again with bits of meat, if available.

Living things are largely composed of carbon and water. The black substance remaining in the container is carbon.

### 23. Seeds absorb moisture

Fill a potato ricer about two-thirds full of seeds. (Navy beans from the grocery are cheap and work well.) Lower the plunger until it is resting firmly on the beans. Tie the handles of the ricer firmly together with several thicknesses of string. Set the apparatus in a pan of water so that the beans can soak. Next morning observe what happened to the string. Considering the leverage exerted by the handles, what does this show about the expansion of seeds as they absorb moisture?

### 24. Seeds contain a tiny plant plus some stored food

Take a lima bean which has been soaked overnight, and with a knife carefully cut around the seed as shown in the illustration.

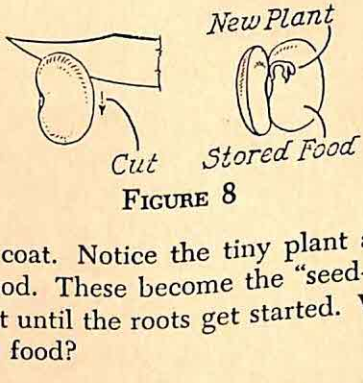


FIGURE 8

Remove the outer coat. Notice the tiny plant and the two broad masses of stored food. These become the "seed-leaves" of the new plant and nourish it until the roots get started. What use does man make of this stored food?

### 25. Molds provide a good example of adaptation

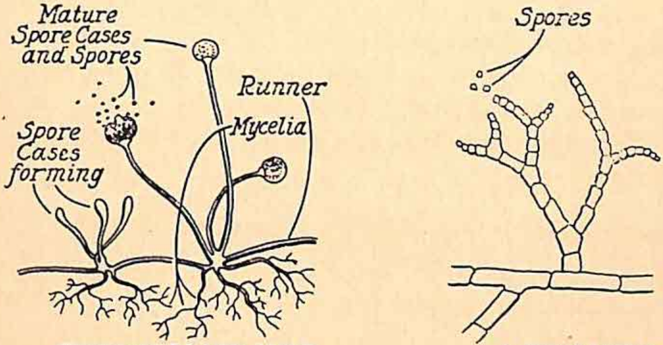
Molds are singularly well adapted to survive unfavorable conditions.[4] The molds which may have started in previous seed sprouting experiments were probably carried in the form of very tiny living spores in the dust in the air. Settling on a place where moisture, food, and a proper temperature were available, they speedily began to grow and reproduce.

The children will be interested in watching molds grow and in

[4] See Jean Broadhurst, *Microbiology Applied to Nursing*, pp. 73-92. J. B. Lippincott Co., Philadelphia, 1936

examining them with a hand lens or a low-power microscope. A "mold garden" may easily be made by slightly moistening a cracker or a piece of bread, exposing it to the air, and setting it aside in a warm, dark place for a few days.

Make several "mold gardens." Put one in sunshine, another in the dark, another in a refrigerator. Which ones grow best? Will a cracker mold if not moistened? Why?



COMMON BLACK MOLD

A PINK MOLD

**Figure 9**

Occasionally more than one kind of mold will start on the same cracker. "Black" mold is most common. Some molds are green, others pink. If pink mold appears, try to grow it by transferring a very little of the pink material to a fresh cracker. Since the materials used have not been sterilized, molds other than the pink kind will probably start in the new culture, but the pink mold may have enough of a head start to crowd out the other kinds.

Examine some mold under the microscope. This may be done by putting a bit of the material in a drop of water on a clean microscope slide and covering it with a cover glass.

A simplified life history of black mold is as follows: As soon as a spore comes to rest under favorable conditions it grows tiny white threads (called *mycelia*) with which to obtain food. Meanwhile the plant puts forth runners. These runners start new mold plants. The mold also grows a stalk upward. At the end of this stalk a spore case forms, containing many spores. This case breaks when mature and the spores scatter to start new plants at new locations. As a result, a single spore soon gives rise to many thousands of plants which cover all available space on the food.

The spores are able to resist drying and hence live through unfavorable periods. The pink molds form spores in a slightly different manner and therefore appear more powdery than the black molds.

Molds are both helpful and harmful. Molds help in decay, thus ridding the earth of undesirable wastes. They are responsible for the desirable flavor of many kinds of cheese. On the other hand, molds cause much food spoilage, and a few are responsible for diseases of man and animals.

### 26. There is water in soil

Fill a dry tin can half full of ordinary "dry" garden soil. Heat the can *gently*. Notice drops of moisture forming on the upper part of the can. Hold a cold glass plate over the mouth of the can and observe the moisture collecting. It is very rare that one finds an entirely dry soil in nature. Instead of a can, a discarded cooking pot which can be covered may be used. Drops of water will form on the inside of the cover.

### 27. Soil contains air

Half fill a large jar with soil. Pour water over the soil until the jar is full and note the air bubbles rising out of the soil through the water. Try different kinds of soil in order to get a rough idea of the different amounts of air they hold.

### 28. Water contains air

Fish breathe by extracting air from water. If there is no air in the water the fish "drown." Green plants in the aquarium help to supply oxygen to the water.

Draw a glass of cold water from the faucet and allow it to remain in a warm room for a while. Air bubbles collect on the glass. When water is boiled, the first bubbles you see are air bubbles.

### 29. Good soil differs from sand in content and structure

Many of the most pressing problems of soil conservation arise from the fact that soil is being lost much faster than it can be replaced by nature.

It is of vital importance for an understanding of these problems to realize that the breaking-up processes, slow as they are, are only part of the changes rocks must undergo in order to make new soil. The broken-up rocks must be changed physically and chemically through the action of living things before soil can be formed. A later experiment in this book deals with some of the processes by which natural forces break up rocks into sand.

Examine saucers of moist soil and of sand with a hand lens or with the binocular microscope.[5] Notice that the soil is composed of sand grains plus dark particles of decayed organic matter. Notice also that the sand grains are loose and separate whereas the soil grains are clumped together in a definite structure. The spaces in this structure hold air and water available for plant root hairs. Beneficial bacteria and other organisms live in soil and help to keep it in good condition and to form new soil. When the soil is allowed to become extremely dry the structure breaks down. The mere addition of water will not restore it; the soil must be reworked either through the natural action of plant roots, earthworms, etc., or by mechanical tilling.

Additional references on soil: A. E. Parkins and J. R. Whitaker, *Our Natural Resources and Their Conservation,* Chap. III, especially pp. 35-43, and Chap. IV. John Wiley and Sons, New York, 1936.

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[5] See note, p. 3.

## CHAPTER II

# *The Atmosphere*

The air is such an important part of the environment that it has been given a chapter to itself. While the child of elementary school age may not be aware of its indispensability to life processes, he probably knows something of the influence of atmospheric conditions on weather and aviation. Teachers should be careful to bring out the importance of air both as a condition necessary to life and as a substance which exerts physical force. They should also stress the air as a part of the earth, not something separate from it.

Experiments dealing with the various phenomena of the atmosphere are especially adaptable for use in the elementary school, since they usually require little in the way of equipment.

### 1. Air is a real substance; it resists objects moving through it

Adults are so accustomed to experiences with air that they do not realize that small children need to have a variety of experiences to show that air is just as real as any other material. Because air is real, it takes work to push it aside. The purpose of streamlining trains or automobiles is to reduce the amount of work necessary to push the air aside as they move forward.

(*a*) Let the pupil take two similar sheets of writing paper or newspaper. Crumple one and leave the other flat. Stand on a chair and drop both at the same time. Which falls faster? Which was heavier? Which had to push aside the most air in falling? What held up one sheet more than the other?

(*b*) Secure a slat of wood about the size and shape of a thin yardstick. Lay it on top of the table with 5 or 6 inches projecting over the edge of the table. Over the part of the stick which is on the table lay 3 sheets of newspaper spread to their largest size. Strike the projecting end of the stick a vigorous blow with a hammer or with the fist. Usually the stick will break before it will push the newspaper through the air.

### 2. Air is real; it occupies space

(*a*) Take a suit box, hat box, or other large and apparently empty box. Cut in one end of the box a hole ½ inch or so across. Squeeze the sides of the box and feel the air come through the hole. Prove that air comes from the hole by letting the air blow dust, feathers, paper streamers, or a candle flame.

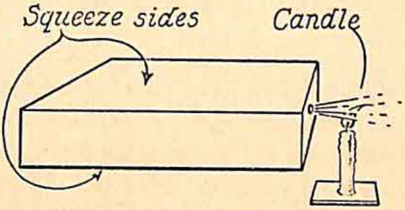

FIGURE 10

(*b*) Hold an "empty" tumbler or bottle upside down and push its mouth under water in a dishpan. A square aquarium tank filled with water may be used for this and succeeding experiments. Notice that the water does not enter because the tumbler or bottle is already filled with something—air. Tilt the bottle or tumbler and notice that air comes out and water goes in. A variation of this experiment is to float a cork on the water. Then push an inverted tumbler over the cork and the cork can be pushed to the bottom without touching it. Or wrap a few matches in a bit of paper and stuff them into the bottom of a glass. Invert the glass and push it to the bottom. Then remove it, take the matches, which of course remain dry, and light the paper with them. The air kept the water out and the matches dry.

(*c*) Float a small cork on water in a dishpan or an aquarium. Hold a hand tightly over one end of a lamp chimney. Place the open end over the cork and push the cork to the bottom. Remove the hand. Feel the air come out as the water goes in. Its level is marked by the cork. See Figure 11, page 18.

(*d*) Have a child hold his finger over the end of a funnel[1] and repeat procedure (*c*). The outward rush of air is easier to feel with a funnel. See Figure 12.

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[1] Glass funnels are available from scientific supply houses at about 28 cents each for funnels 3 inches (75 mm.) in diameter.

Rubber tubing in the best grade costs about 10 cents a foot, in lengths of 5 feet or more. Shorter lengths are not sold. Cheaper grades are not recommended. It is suggested that two sizes of rubber tubing be kept on hand: ¼ inch and 3⁄16 inch inside diameter.

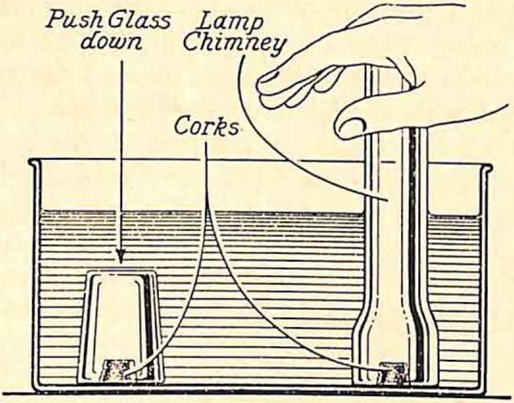

FIGURE 11

(*e*) Fit a rubber tube over the end of a glass funnel. Hold the funnel upside down on the bottom of a pan of water. The pupil should blow air into the tube and force the water out of the funnel.

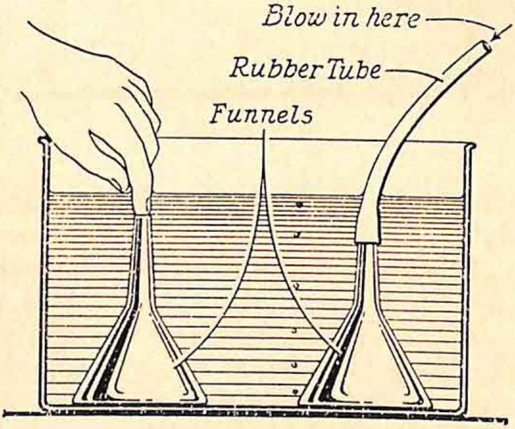

FIGURE 12

This illustrates the principle of the caisson by means of which men can work on the bottom of a body of water. A caisson is a large airtight box, open at the bottom. Air forced into the box keeps the water out. Men working in the caisson are subjected to increased air pressure, for the air pressure inside the caisson must equal the water pressure outside.

(*f*) Submerge a tumbler full of water, and hold it bottom up in a tank of water. Place one end of a piece of rubber tubing inside the inverted tumbler. Blow air through the tube. As the tumbler is filled with air the water is forced out. If the end of the rubber tube inside the tumbler is held so that the air can get out again, the water will come back into the tumbler.

(*g*) Pouring air. Air is so real it can be poured like water, but the pouring must be done upside down. Have two inverted tumblers under water. One must be full of air and the other full of water. Hold one in each hand. Get the rim of the one that is full of air a little inside the rim of the one that is full of water, and tilt the tumbler of air slightly. Air will pour upward and force the water out of the tumbler which was full of water. Try to see how little air can be spilled. Now pour the air back again.

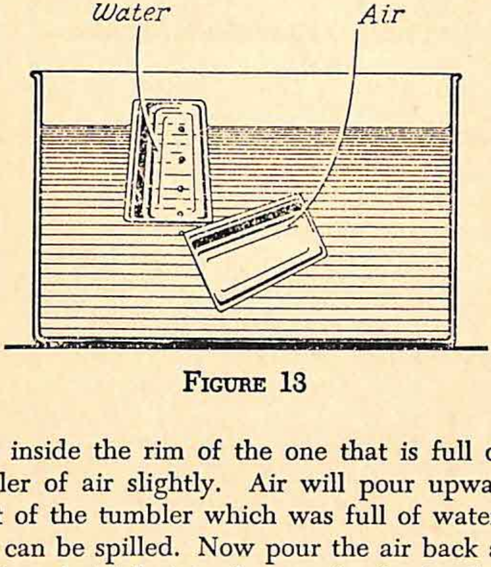

FIGURE 13

(*h*) Fit a funnel tightly into the mouth of a bottle or jug. This may be done by passing the stem of a glass funnel through a one-hole rubber stopper. Try to fill the bottle with water, using the funnel. The bottle is full of air and therefore cannot be filled with anything else. Loosen the stopper to let the air out and try again. Why are many funnels fluted at the stem?

(*i*) Pour water from a narrow-necked bottle or jug. The jug gurgles because air must come in as the water goes out. Tilt the jug only a little so that water does not fill the neck; then the water will pour smoothly, for air can enter freely.

### 3. Air presses

In a sense, all air pressure experiments show that air is real, for air presses because it has weight, and it has weight because it is real.

(*a*) Take a clean piece of glass tubing [2] to represent a drinking straw. Pass it through a one-hole stopper [3] and fit the stopper tightly into a bottle of water. Try to drink through the straw. Now loosen the stopper so that air can press on the water freely, and try to drink again. If there is much air and little water in the bottle a small amount of water will come out even when the stopper is tight, because the air in the bottle is elastic and "stretches" a little.

*Note:* To put the tube into the stopper more easily, wet the tube and the stopper. Take them apart again as soon as you are through with them to prevent sticking.

Drinking straws work because air presses on the liquid and forces it up the straw when some of the air is sucked upward out of the straw. If the air cannot press on the liquid the straw will not work.

(*b*) Punch a small hole in the bottom and another in the top of a can which is fitted with a tight cover. Fill the can with water. The water will run out the bottom hole as long as the top hole is open, but if the top hole is closed the water soon stops flowing. The air presses against the water as it comes through the hole without being able to press equally on the top of the water. Thus the air pressure holds the water back. If the can is only partly full, the elasticity of the air inside the can allows the water to keep on flowing for a while. One punches two holes in an evaporated milk can so that the air may come in as the milk runs out.

(*c*) Examine various suction devices, such as suction cups for "sticking" to glass, plumbers' sink pumps, eye droppers, plant sprinklers (the type with a rubber bulb), etc. What makes them work? Why will not suction cups work on a rough surface? Why do they work better if they are wet first? Attach one to a smooth surface and notice how strongly it must be pulled to get it off again. Measure the diameter of a suction cup; then calculate its area. (The area of a circle is about 3.14 times the square of one-half its diameter.) Multiply the area by 15, because air presses with a force of about 15 pounds on each square inch of surface. The answer approximates the degree of force necessary to pull the cup loose.

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[2] Glass tubing is sold by the pound for about 55 cents a pound. Two sizes are recommended: 6 mm. and 8 mm. outside diameter. One-half pound of each size is enough. Glass tubing, for some obscure reason, is measured in millimeters outside diameter, while rubber tubing is measured in inches inside diameter. The sizes of rubber tubing recommended on page 17 fit 6 mm. and 8 mm. glass tubing.

[3] For many purposes a cork stopper which has had a hole burned in it with a hot nail may be used, but rubber stoppers will be found more satisfactory. They cost from 15 cents to 30 cents a dozen, depending on the size. Two pounds of assorted rubber stoppers cost about $1.50.

(*d*) Take a piece of glass tubing a foot or so long. Place a forefinger tightly over the end. Plunge the tube straight down in a pan or jar of water, the deeper the better. Water will not enter the tube because the air keeps it out. Remove the finger. Water enters. Replace the finger and remove the tube. The water remains in the tube because the air is pressing on the bottom, but it cannot press on the top, as the finger is in the way. This "dip tube" is useful in removing bits of dirt or other foreign matter from the bottom of the aquarium or in transferring a few drops of a liquid from one container to another.

(*e*) Spill the air from a tumbler and invert it under water. Hold the filled inverted tumbler and lift it straight up. As the tumbler is lifted the water stays inside it until the air has a chance to get in. Watering fountains for poultry and the types of drinking water coolers which have a large bottle of water inverted on top are based on this principle.

(*f*) Fill a tumbler with water. Over the mouth place a piece of thin card or oaktag. Hold the card in place and turn the tumbler over. Remove your hand. The card stays in place, held there by air pressure. The air cannot press on the water inside of the glass because the glass is in the way; hence the water stays in. Repeat the experiment with the glass only partly full of water. It is a little more difficult, but can be done with practice. A fresh card may be necessary. This experiment is especially good because it shows that air presses upward as well as downward.

(*g*) Using a one-hole rubber stopper, a short piece of glass tubing, and a rubber tube, connect an "empty" jug to a vacuum pump. Use a vacuum pump (called an *aspirator* or a *filter pump*)[4]

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[4] An aspirator which gives a very adequate vacuum may be obtained for about $1.35 from a scientific supply house.

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which attaches to the water faucet as shown in the illustration. This type of pump uses the force of running water to create a vacuum. Make sure that all connections are airtight and that the stopper is fitted tightly in the jug. Have a basin of water ready. When everything is connected turn on the faucet and allow the water to run through the vacuum pump for a few minutes or until the waste water runs clear and free from air bubbles. If this does not happen within three minutes, something is probably allowing air to leak into the jug or tube.

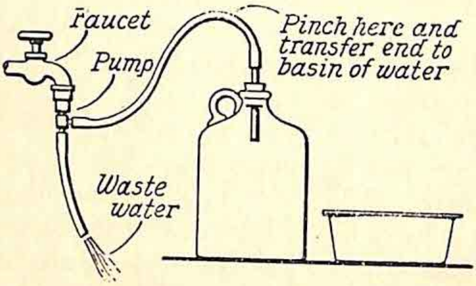


FIGURE 14

Now double over the rubber tube leading to the jug and pinch it firmly to prevent any air from entering. With the aid of another person shut off the water and remove the rubber tube from the vacuum pump. Submerge the free end of the tube in the basin of water and release it. Some water should immediately flow into the jug. Raise the basin slightly, and more water should flow.

The vacuum pump removed some of the air from the jug. When the tube was released, air pressing from the outside tried to get in. The water in the basin was in the way, and the air pushed it in.

The amount of water that enters the jug is a rough measure of the amount of air that was taken out.

If no vacuum pump is available, some air may be sucked out by mouth, but not as much as with a pump.

(*h*) In place of the jug in the above experiment, use a varnish or other tin can into which a stopper can be fitted tightly; as the air pressure inside becomes less, the air pressure outside will crush the can.

(*i*) Take a varnish can or other tin can which can be stoppered tightly. Put the can on the floor. Place a wide piece of board on the can and stand on the board to prove that the can is strong.

Place a small amount (½ cup) of water in the can and heat the water to boiling. When the water is boiling vigorously, turn off the heat and stopper the can tightly. A rubber stopper is best. Allow the can to cool or pour cold water over it. The can should soon crush.

When the water boiled, some of it turned to steam. The steam forced the air out of the can. As the steam cooled it turned back to water. This left the inside of the can empty of both air and steam. There was therefore little or no air pressure inside the can. The air pressure outside crushed the can.

Measure the can and calculate its total area. Assume an air pressure of 15 pounds on every square inch of the can. What was the total force crushing the can?

(*j*) The siphon. Have an empty jar and a jar full of water, with the full jar higher than the empty one. Take a piece of rubber tube 2 or 3 feet long. Hold the two ends of the tube in a U-shape and fill the tube entirely full of water under the faucet. Close both ends with the fingers. Place one end under water in the full jar and the other end in the empty jar, and release them. The water should flow freely. When the first jar is partly emptied, raise the low jar higher than the first jar. The water will now run back again. The water falling down the long side of a siphon creates a vacuum at the top of the inverted U. Air pressing on the water in the jar pushes the water up to fill this vacuum. This keeps the siphon going.

The siphon tube can be filled in a number of ways. Sucking on it is the simplest, but is not applicable to poisonous or unpleasant liquids. Placing the empty tube in the jar of water in such a way that the air can leave the tube freely, thereby allowing the water to fill it, is another good way.

The siphon is very useful in cleaning an aquarium. If the tube used is big enough it is possible to remove the layer of dirt at the bottom of the aquarium without removing much water.

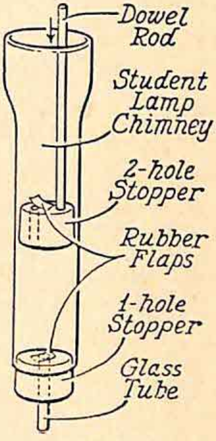


FIGURE 15

(*k*) Pumps. Many if not all kinds of pumps depend upon air pressure. A simple working model can be made. See Figure 15.

Secure a "student lamp" chimney and a two-hole rubber stopper which will slide inside the chimney and still fit it closely. Take a wooden dowel rod, somewhat longer than the chimney, and fit it into one of the holes, gluing it in place. Secure a one-hole rubber stopper which will close the small end of the chimney. Insert a glass tube 3 or 4 inches long part way through this stopper.

Now cut two pieces of thin rubber sheeting or bits of rubber balloons and glue them (or use rubber cement) as flaps to cover the hole in the one-hole stopper and the vacant hole in the two-hole stopper. These bits of rubber are to act as valves to let water through the holes in one direction only.

Assemble the pump as shown in Figure 15. Insert the tube in water and work the dowel rod. Work it gently at first, as it splashes otherwise.

### 4. Air presses because it has weight

The following experiment is inserted here for the sake of completeness to prove that air has weight. It will not work unless it is done with great care.

Bore small holes through the 6-inch, 18-inch, and 30-inch marks of a yardstick. Suspend the yardstick from a loop of string through the middle hole. Suspend from one end hole a basketball blown up hard. Suspend a coffee can from the other end hole. You now have a crude balance to weigh the basketball. Add sand to the coffee can until it just balances the basketball. Now *without changing anything else* release the air from the basketball. Some sand must be removed from the coffee can in order to balance the empty ball, showing that releasing the air made the ball lighter.

### 5. A barometer measures air pressure

The instructor may demonstrate how to set up and use mercurial barometers, and show a model aneroid barometer. (See G. S. Craig, *Science for the Elementary School Teacher*, pp. 192-194. Ginn and Co., Boston, 1947.)

### 6. Air is elastic

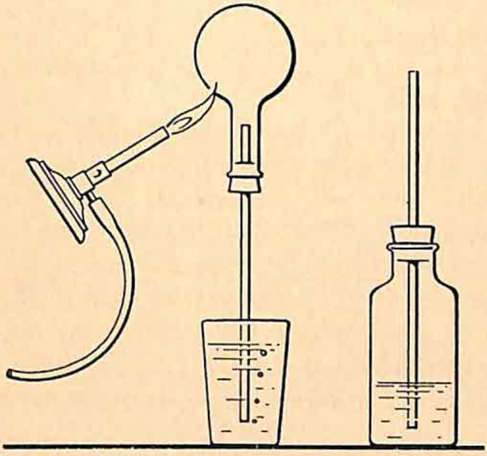
(*a*) Fill a bottle very nearly full of water. Wet a cork (to reduce friction) and force it suddenly into the bottle by striking it with your fist. The small amount of air in the bottle is so elastic that frequently it will force the cork slowly out again. For this reason one often has trouble in putting corks into bottles containing oily materials.

(*b*) Fill a jug or large bottle half full of water. Through a one-hole stopper pass a glass tube long enough to reach the bottom of the jug, with its outer end drawn out to a nozzle. Insert the stopper in the jug and blow hard through the nozzle. It will be seen from the bubbles that air is being forced into the jug. Step back and watch what happens when this air tries to get out again.

(*c*) Suggest that the children notice compressed air tools, such as riveting machines and pavement breakers in action.

### 7. Air expands when heated

(*a*) Fit a small balloon over the mouth of a chemical flask or a Pyrex nursing bottle. Heat the bottle. The air within will expand and partially fill the balloon.



(a) (b)

FIGURE 16

(*b*) Arrange a flask or Pyrex nursing bottle with a long glass tube and one-hole rubber stopper as shown in Figure 16(a). Invert the flask and support it so that the end of the glass tube dips into a container of colored water. Heat the flask, gently at first and then more strongly. Notice the air bubbles coming out through the colored water. Allow the flask to cool, and notice how the outside air pressure forces the water up the tube as the air in the flask contracts. A candle may be used to heat the flask.

This arrangement could be used as a kind of thermometer. The liquid will go *down* as the temperature gets hotter. This is the original type of thermometer, invented by Galileo.

(*c*) Arrange a bottle, a one-hole stopper, and a glass tube, as shown in Figure 16(b). Have the glass tube almost but not quite touching the bottom of the bottle. Place an inch or two of colored water in the bottle. Warm the bottle with the hands and notice what happens as the air inside expands.

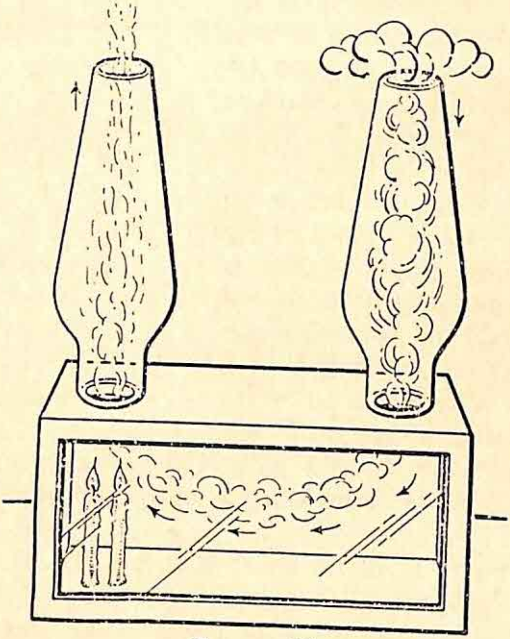


FIGURE 17

(*d*) Hard boil an egg and remove the shell. Set fire to a piece of paper about half the size of an 8½ × 11 inch sheet. Thrust the burning paper into a milk bottle and *quickly* place the egg (end up) on the mouth of the bottle. Notice that the egg "dances" for a second or two and then goes into the bottle with a loud "pop." Explain how this experiment works, remembering that heat causes air to expand.

### 8. Heated air is pushed up by cold air

(*a*) Clap erasers over a hot radiator. Then clap them very close to the glass of a window on a cold day. Clap them at the side of the room opposite the radiator. What does the movement of the chalk dust in these three places indicate concerning the movement of heated air and cold air?

(*b*) On a calm day in winter in a heated room open a window a few inches at the top and bottom. Tack a few crepe paper streamers so that they hang across the openings. Notice which way the air is moving as shown by the streamers. Why should you choose a winter day rather than a summer day?

(*c*) Arrange a box about a foot long with a glass front and two holes in the top into which lamp chimneys may be fitted. Place candles inside the box under one of the holes. Light the candles and close the glass front. Dampen a paper towel and set on fire to produce smoke. Some practice is necessary to learn the right amount of dampening. Hold the smoking paper first over one chimney and then over the other. See Figure 17. In which one is the air rising and in which one is it descending? What is the path of the air currents inside the box? How does this compare with the movement of air in a heated room?

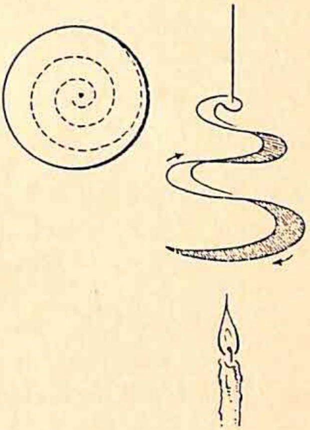


FIGURE 18

(*d*) Cut a circle of paper about 6 inches across. It need not be an accurate circle. Make a pinhole at its center. Draw a spiral from some point on the rim of the circle to the center, as shown in Figure 18. Cut along the spiral with scissors. Pass a thread (not a string) through the pinhole and knot it so that the spiral can be suspended by the thread. Hold the paper spiral over a source of heat, such as a candle, stove, electric heater, or radiator.

### 9. There is water in the air

(*a*) Take several containers of different shapes, such as a pan, a tumbler, a milk bottle, a narrow-necked bottle, and a bottle with a stopper. Place equal amounts of water in each of the containers. (Why use equal amounts of water?) Place all the containers in the same place. (Why?) Next day look at the amount of water remaining. Which has lost the most and which the least water?

(*b*) Take two similar open containers and put the same amount of water in each. Put one in a warm place and one in a cool place. Which loses water faster? Why?

(*c*) Breathe on a cold glass plate. Where does the water come from? What is one substance that animals are putting into the air all the time?

(*d*) Put a shiny container of cold water over a flame. Water appears on the outside of the container when it is first put over the flame. The water is formed as the flame burns.

(*e*) Refer to Experiment 19, in the chapter on plants. Plants also put water into the air.

### 10. Warm air can hold more moisture than cold air

Fill a clean, shiny, tin cup with ice water. Notice the moisture which forms on the outside of the cup. Try to wipe it off. If desired, add color to the water inside the cup to prove that the cup does not leak. Warm, moist air coming in contact with the cup is so chilled that it can no longer hold as much moisture, and the moisture is deposited on the cold cup. Dew is formed in this way.

This experiment also shows how water gets out of the air. Rain is caused by cooling moist air.

### 11. Clouds are made from the water in the air

Boil water in a teakettle. Notice the cloud of white material which forms near the spout, but not directly at it. This is a true cloud, caused by the cooling of the steam which comes from the kettle.

Notice the seemingly empty space at the spout. This space is filled with water in the gaseous state (steam). One cannot see steam.

### 12. Evaporation cools things

(*a*) Take an ordinary flower pot (a new clean one is preferable) with a stopper in the drainage hole and soak it in water an hour or two. Then fill it with water. At the same time fill a glass jar of about the same size as the flower pot with water. Some water seeps through the porous pot and keeps the outside wet. Arrange an electric fan to blow equally on both containers for a few hours. Notice the temperature difference, if any, between the water in the porous pot and that in the non-porous jar. What function does the jar play in this experiment? What effect does evaporation of perspiration have on the human body? Why do we wear porous clothes in summer? Why is a humid day more uncomfortable than a dry one when the temperature is high? If evaporation cools, what would one expect condensation to do? Ask the children to discuss what effect the condensation of rain would have on the air?

(*b*) Take two thermometers.[5] Around the bulb of one tie a single layer of clean handkerchief linen or cheesecloth which has been washed to remove the starch. Tie the cloth in place with a thread. Wet the cloth in water at about room temperature. Hold the two thermometers in front of the electric fan and watch their readings. Which one is cooler? Hold the dry thermometer back of the fan. Is the air in front of the pan any cooler than the air behind it? How does the fan cool a person? Would the difference between the readings of the wet and the dry thermometers be greater if the air in the room were very dry, or would it be less?

### 13. Fire needs air to burn

(*a*) Build a fire of small sticks on an asbestos pad. When it is burning, throw some sand on it. Sand puts out fire for two reasons: it cuts off the air from the fire and it cools the burning material.

(*b*) With wax fasten several birthday candles to small squares of cardboard. Have ready a number of glass jars of different sizes. With the aid of one or two assistants, invert the jars over the burning candles all at the same time. Which flame goes out first? Force the old air out of the jars by filling them with water or by waving them about, and repeat the experiment. Does the candle under the smallest jar always go out first? How can one prove that this effect is not due to something about the candle itself, i.e., that one particular candle does not always go out first regardless of which jar is over it?

### 14. Fire uses up part of the air

(*a*) After the candles have gone out in the previous experiment, quickly but without unnecessary stirring of the air, lift one of the jars from over the candle and set it upside down on the table. Relight the candle and replace the jar over it. Does the candle burn as long as it did when fresh air was used?

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[5] Chemical thermometers are recommended in several places in this book. A particularly satisfactory one contains red liquid, making it easy to read. It goes from 10° to 220° F., and costs $1.50. Cheaper ones filled with mercury instead of red liquid may also be obtained, but they are much harder to read.

(*b*) Pour a small amount of fresh limewater[6] into a jar containing air in which a candle has burned. If the limewater turns milky it shows the presence of carbon dioxide. The carbon dioxide was formed from the oxygen of the air and carbon from the burning candle.

(*c*) Moisture often appears inside a jar in which a candle has been burned. This water is made of oxygen from the air and hydrogen from the burning candle. Therefore fire uses up part of the air to make carbon dioxide and part of the air to make water.

### 15. Breathing uses up part of the air

(*a*) Fill a quart jar with water and invert it while full in a basin of water. Push the end of a rubber tube up inside the jar and blow into the tube. The breath will displace the water in the jar, leaving the jar full of exhaled air. Cover the mouth of the jar with a glass plate and remove it from the basin. Have a child lower a burning candle fastened to a wire into the jar of exhaled air and at the same time have another child lower another candle into a similar jar of fresh air. Which candle goes out more quickly? What was the purpose of the second jar?

(*b*) Fill a tumbler about one-fourth full of limewater. Have a child blow his breath through the limewater with a soda straw or glass tube. How does the limewater change? What does that show? If carbon dioxide is found in the breath, what could have been the source of the carbon? What could have been the source of of the oxygen? What two sources of carbon dioxide in the air are shown by Experiments 14 and 15. What becomes of some of the carbon dioxide in the air? What is another substance found in the breath? (See Experiment 9*c*.) This experiment proves that breathing uses up part of the air because the oxygen of the air was used to make the carbon dioxide. Oxygen was also used to make the water in Experiment 9*c*.

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[6] To prepare limewater throw a handful of builder's slaked lime into a gallon of water, stir, allow the lime to settle, and carefully pour off a quart or two of the clear liquid. Save the clear liquid, which is limewater, and throw the rest away.

### 16. The pressure of the air affects the boiling point of water

Fill a Pyrex flask (or a Pyrex nursing bottle) about one-fourth full of water and bring the water to a boil. Turn off the fire and stopper the flask firmly, preferably with a solid rubber stopper. Hold the flask with a cloth while cold water runs on it or it is cooled with ice water. The water should resume boiling as the flask is cooled. How cool can the water get and still boil?

The explanation of this experiment is something like that of Experiment 3*i*. As the water boils steam is formed. This steam presses on the water and keeps it from bubbling. When the flask is cooled the steam is condensed and a vacuum remains. Now there is little pressure, either of air or of steam, to prevent bubbling, and the water boils easily. What effect does this have on cooking in higher places when the air pressure is low? How can one account for the great speed of the pressure cookers which are now widely advertised? (For a fuller explanation see G. S. Craig, *Science for the Elementary School Teacher*, pp. 196-197.)

### 17. Oxygen is the gas in the air which helps things to burn

(*a*) Secure a quart fruit jar and stand it in a shallow pan. The pan is for safety in case the jar should crack. Put a piece of "oxone" (fused sodium peroxide) about the size of a walnut, or a little larger, in the jar. Always handle oxone with pliers or forceps, never with bare hands. Add about one-half cup of water and cover the jar with a glass plate. Chemical action will immediately be seen and a gas will be given off, as shown by the rattling of the plate. This gas is oxygen.

Set fire to a splint of wood, and after the chemical reaction has been going on for a few seconds, blow out the flame and place the glowing end of the splint in the oxygen. The wood will immediately take fire again. Do not remove the glass plate entirely, merely slide it a little to one side, so as to lose as little oxygen as possible.

(*b*) Fasten a birthday candle to a piece of wire, set fire to it, and lower it into a jar of oxygen. Compare its speed of burning with a similar candle burning in air.

(*c*) Iron picture wire heated to redness and plunged into a fresh jar of oxygen can often be made to burn brilliantly.

(*d*) To show that oxygen is lighter than air, attempt to repeat part (*a*) or (*b*) of this experiment, using a jar of freshly prepared oxygen which has been allowed to stand uncovered for a minute or two.

*Caution:* Do not get any of the liquid remaining in the jar on hands, clothes, or furniture, as it is a strong alkali.

When the experiment is finished, place the jars in the sink to cool; when cool rinse them out with water.

### 18. Carbon dioxide is a heavy gas which puts out fire

(*a*) Place about two tablespoons of washing soda in a tumbler, the taller the better. Place the tumbler in a large container, such as a battery jar. Pour some concentrated hydrochloric acid[7] on the soda, and cover the jar with a glass plate. In a minute or two reach into the jar and quickly remove the tumbler of soda and acid. The jar now contains carbon dioxide. Test the carbon dioxide with a glowing splint as was previously done with oxygen in Experiment 17. What happens? Test it by lowering a lighted candle into it. What does the candle do? Allow the jar to stand uncovered in a place free from drafts for a minute or two and test again. Does the carbon dioxide tend to remain in the jar?

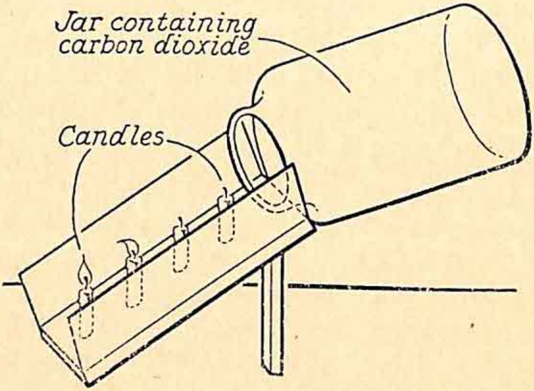

FIGURE 19

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[7] Vinegar and baking soda may be used instead of hydrochloric acid and washing soda. About half a pint of vinegar must be used. Add it to the baking soda a little at a time, so as to avoid excessive foaming and spattering. This method is useful in case the teacher for any reason deems it inadvisable to use hydrochloric acid. "Dry ice" is made of "frozen" carbon dioxide, and a jar of carbon dioxide gas may be obtained by leaving a piece of dry ice in a jar for several minutes. Handle the dry ice with forceps or pliers.

(*b*) Make a "carbon dioxide trough" of a slanting board 14 inches or so long and 2 inches or less wide with cardboard sides and holes in the bottom in which to place candles, as shown in Figure 19.

Prepare a large jar of carbon dioxide and cover it with a glass plate. Light the candles in the trough. Pretend that the jar is full of water, and try to pour the "water" down the trough. Have an assistant hold the glass cover on the jar until it is tilted, and then remove the cover. If this is done skillfully the candles will go out one by one, beginning with the topmost. What does this show about carbon dioxide?

(*c*) Prepare a jar of carbon dioxide as in (*a*) above, taking care not to splatter any soda or acid in the jar. Remove the tumbler of soda and acid; then pour some fresh limewater into the jar and shake it about. What happens to the limewater? As explained in Experiment 14*b*, when limewater turns milky it shows the presence of carbon dioxide.

## CHAPTER III

# *The Story of the Earth*

The story of the earth lends itself better in the elementary school to field work, reading, and discussion than it does to laboratory work. The author has also found it desirable to make liberal use of lantern slides.

The experiments included here are largely designed around a theme of "speeding up time." They attempt in a few hours in the laboratory or classroom to illustrate actions which require thousands or millions of years in the out-of-doors. For example, Experiment 4 uses a strong, relatively concentrated acid to produce in a few hours an effect which requires years to take place naturally through the action of carbonic acid which is weak and highly diluted. The teacher should emphasize that these experiments show most of all that the earth is very old.

Time and change are the integrating themes in this chapter. The teacher should stress the immense stretch of the past and the probable length of the future. During this long past the earth has undergone tremendous change. Mountains have risen and been torn down; seas have drained and filled again; species have flourished and passed away. These processes are going on at the present moment, probably with undiminished rapidity. The teacher should try to get children to see that changes similar to those in the past are probable in the future. The old cataclysmic theory which implied that all the important changes happened suddenly in the past and are now finished is unfortunately deep-rooted not only in child minds but in adult minds as well.

### 1. Rocks may be worn away by friction

The children may make sand and mud by rubbing rocks together. Only a little sand is made, and the rocks are not smoothed much, which will give the children some idea of the great length of time necessary to wear smooth the rocks and boulders they see around them. Even when sand is produced, it is not yet soil, as the children may see by comparing sand and soil under a hand lens. Still more time must elapse before sand is changed into soil. In the earth the soft rocks wear away first, leaving the harder rocks standing out as hills, ridges, or mountains.

### 2. Rocks may be broken by the action of freezing water

(*a*) Fill a bottle with water and stopper it. If possible allow it to freeze outdoors. The expansion of freezing water bursts the bottle. Direct the pupils' attention to the similar process when water which may be in the pores and cracks of rock freezes and pieces of the rock are broken off.

(*b*) To prove that water actually does enter rock, wet a relatively porous rock, such as a piece of sandstone. It cannot be wiped dry with a towel.

### 3. Heating and cooling helps break up rock

A rock when heated and cooled breaks up into small pieces. The desert regions of the earth are subject to such heating and cooling. Heat a piece of quartz or feldspar in a flame for several minutes; then plunge it into cold water. The rock should show signs of breaking up.

### 4. Chemical action helps break up rock

Marble and limestone show chemical action when immersed in dilute hydrochloric acid. If this action goes on for a time, the rocks break up. Ground water is much less acid than even dilute hydrochloric acid—its action is much slower. Immerse a piece of marble or limestone in a cup of water, add about 4 tablespoons of hydrochloric acid, and leave for a few hours. Notice that the rock appears to be somewhat worn away, and that there is a little sand or mud in the liquid. Caves are formed in limestone by the action of slightly acid ground water. Instead of using hydrochloric acid, a piece of marble may be boiled in vinegar.

### 5. Some rock materials may be deposited as crystals

Hot water dissolves substances more readily than cold water. Direct the pupils to try to dissolve 3 tablespoons of washing soda in one-half cup of cold water. The soda will not dissolve. Then heat the water and note that the soda dissolves. Continue heating the water and add more soda until no more will dissolve. Do not boil violently and do not add enough soda to make the solution milky.

As hot water carrying dissolved substances cools, the substances may be deposited as crystals. Allow the hot solution to cool and note that the soda is deposited. Quartz veins in rocks may have been formed when hot volcanic water carrying dissolved quartz material cooled. The material may also be dissolved in liquid (molten) rock. For this experiment materials other than soda may be used. For example, either copper sulphate or Rochelle salt yields fine crystals.

### 6. Rock materials may be deposited as layers or strata at the bottom of lakes, ponds, or seas

When a mixture of dirt, sand, etc., is carried into still water, the heavier particles sink first. The mud which collects at the bottom shows layers (strata). The mud which later hardened into sedimentary rock was stratified in this manner. Throw two double handfuls of garden soil into a gallon jar of water, mix well, and allow to settle. Notice the layers in the mud. Strata are always formed in a horizontal position. If they are found folded or tilted, it indicates that some force must have folded or tilted them after formation.

### 7. Fossils are records of life in the past

Fossils indicate that there was life in past geological ages. They were formed in several ways. In one process, the shells, bones, leaves, or other parts of organisms were buried in mud which later hardened into rock. Although the original organism may have disappeared, the rock retains a print or cast of it. Mix plaster of Paris with cold water to the consistency of thick soup. Drop spoonfuls of it on paper or cardboard. When the mixture is hard enough to retain a print, the children may press into it shells or leaves which have previously been covered with vaseline or oil. In one or two hours the shells, leaves, or other objects may be removed. The prints will remain in the plaster.

### 8. Some rock materials have come from volcanoes

A model "volcano" which often proves interesting to children may be made as follows:

Prepare a mound of damp newspaper about 6 inches high and 10 inches in diameter. This is to be the core of the model. To about 6 cupfuls of dry plaster of Paris in a dishpan add quickly enough water to make a thin paste. Stir well, but do not take more than 2 minutes to add the water and stir, or the plaster will begin to harden.[1] After mixing, wait until the plaster shows signs of thickening, then cover the core of paper with a layer of plaster about 1 inch thick. A spoon may be used to mold the plaster, but it is better to use your hands.

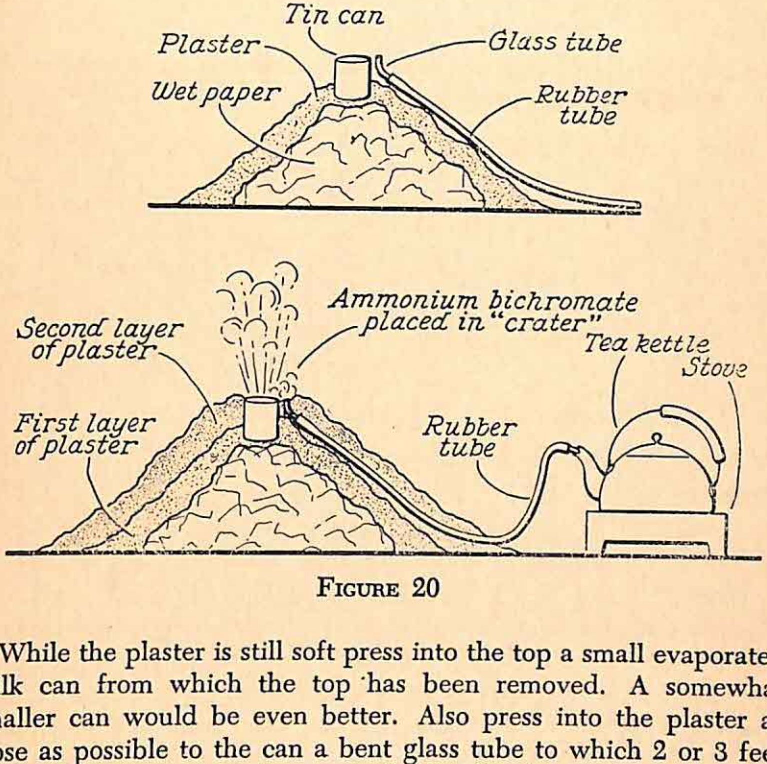

FIGURE 20

While the plaster is still soft press into the top a small evaporated milk can from which the top has been removed. A somewhat smaller can would be even better. Also press into the plaster as close as possible to the can a bent glass tube to which 2 or 3 feet of rubber tubing have been attached. The can will serve as the "crater" of the volcano, while the tube will carry steam. At this stage the volcano should look like the first illustration above.

Mix more plaster and apply it to the volcano to build it up around the crater, as shown in the second illustration above. The other end of the rubber tube is connected by means of a glass tube and a one-hole stopper to a teakettle which serves as a steam generator.

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[1] The hardening of plaster is a chemical process, and once it has begun to harden, adding water will only result in making mud. *Do not* add any water after plaster has begun to harden.

When the plaster is hard, fill the crater nearly full with small crystals of ammonium bichromate, which may be ordered through a druggist. Start the steam generator and at the same time set fire to the bichromate. It will burn, giving off sparks and a great deal of a greenish powder which rolls down the mountain to represent lava. Some of the green powder will drift around the room to represent volcanic ashes.[2] The steam represents the steam and smoke of a real volcano.

This demonstration is more spectacular in a darkened room.

### 9. Clay models may be used to illustrate geological concepts

Models of various geological formations, such as folds or faults in the earth, are easily made of colored modeling clay or Plasticine. Make "pancakes" of well-worked clay to represent each rock layer. Lay the pancakes together and trim the edges with a sharp knife. Then fold the layers, or cut them to represent faults, etc. A little ingenuity on the part of teacher and children will enable them to represent any desired formation. The trimmed-off pieces may be separated and the scraps of Plasticine saved.

For illustrations of the sort of thing that can be shown by clay models it is suggested that the teacher look at the "block diagrams" in a good standard text on geology.[3] Better still, let the children model in their own way the things they have seen on field trips.

[2] Ammonium bichromate will not explode. The green powder given off may be easily brushed from clothes if it gets on them. Do not allow ammonium bichromate to remain on the skin or get into the eyes. Beware of other mixtures which are occasionally suggested for similar demonstrations, especially ones containing potassium chlorate.

[3] See, for example, *Physical Geology*, by Chester R. Longwell, Adolph Knopf, and Richard F. Flint (John Wiley & Sons, Inc., 1932) or *An Introduction to Geology*, by W. B. Scott (Macmillan Co., 1932).

## CHAPTER IV

# *Seasonal Change and the Movements of the Earth and Moon*

Probably no idea is more important to understand than the absolute dependence of the earth and its life upon the sun. One way to bring this out is by enlarging a child's understanding of the causes back of day and night and of seasonal change. From the kindergarten when the child notices the melting snow and the bursting buds on throughout his life nothing is more important than the fact that spring comes again and again.

Unfortunately seasonal change has sometimes been taught as an academic exercise from a book and sometimes solely from the emotional or esthetic standpoint. This chapter attempts to give reality through a concrete demonstration of the causes of the varying amounts of sunlight received by a place during the year.

The material is described in this chapter as though it were one long demonstration,[1] which is the form in which the author uses it in teacher training. The teacher must select from the chapter material suited to the needs of her particular pupils. For example, a first grade child might conceivably be shown a globe and told that it is a "picture" of the world, whereas a sixth grade child might want to know why globes are marked with lines called the tropics.

Secure a geographical globe and a projection lantern or a good flashlight. A lantern is greatly to be preferred since it can be focused in the particular way best adapted to each demonstration. The author prefers a 16-inch globe on a plain stand without a meridian ring, but other kinds of globes work nearly as well. Provide also a stand or box for the lantern of the right height so that when the beam of the lantern is aimed horizontally, the center of the beam falls rather accurately on the center of the globe.

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[1] For descriptions of similar demonstrations, together with much additional information, see G. S. Craig, *Science for the Elementary School Teacher*, Chap. IV, Ginn and Co., Boston, 1947.

Mark the directions north, south, east, and west in the room. Cards bearing the names of the directions hung in the appropriate places are suggested.

### 1. Day and night are caused by rotation of the earth on its axis

Place the lantern on its stand on the floor, turn it on, and push the lens in as far as it will go in order to get a broad beam (or rather cone) of light. Place the globe on the floor as far away from the lantern as circumstances will permit and throw the beam of light on the globe. Darken the room.

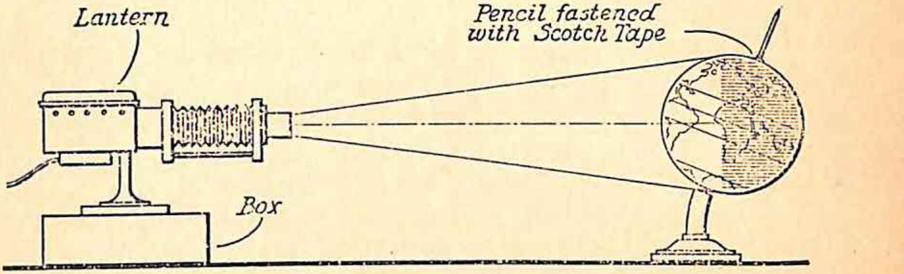

FIGURE 21

Notice that only part of the globe is lighted. Direct the children to find on the globe the place where they live. Turn globe and notice that any given place is alternately in the light and darkness.

In which direction does the real sun seem to rise? Get the children to turn the globe until the place where they live is just on the edge of the darkened part. Hold one end of a pencil on this place and point the other end toward the "sun." Does it point toward the east or the west of the globe? Does the setup represent sunrise or sunset? Perhaps the children know that about the time of sunset places to the east of them (such as London) are already having night, while places to the west (such as San Francisco or Hawaii) are still having daylight. Which way must the globe be turned to make it night in London before it is night in New York? The children will find as they look down on the globe that it must turn counterclockwise.

### 2. The length of day and night are not always the same

Clear as much space as possible in the center of the floor. Use a string as a radius and draw a large chalk circle on the floor to represent the earth's orbit (see Figure 22). Place the lantern on its stand in the center of the circle, push the lens in, and direct the light toward the globe. The globe should be on the floor on the edge of the circle at the north side of the room, with its axis tilted 23.5° from the vertical and pointed north. It may be helpful to extend the axis by means of a pencil or stick of wood fastened to the top of the globe with Scotch tape or a lump of Plasticine. Such an extension makes it easier to see which way the axis is pointing.

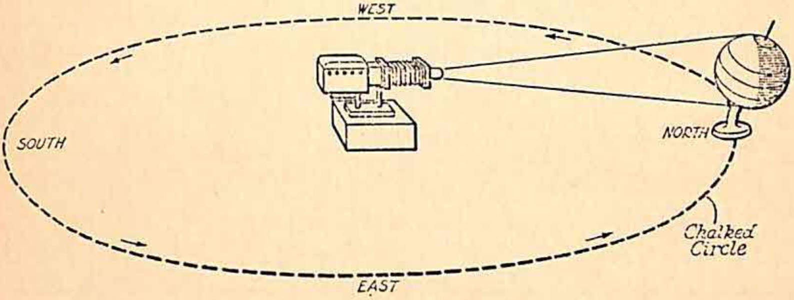

FIGURE 22

If the school is located more than 35° north or south of the equator, have the children find its location on the globe. If it is closer than 35° to the equator, select some place in a middle latitude such as New York, Chicago, or Toronto.

Notice that the night is longer than the day in places in the northern hemisphere (if the globe is placed according to directions). Notice also that in the northern hemisphere the earth's axis is tilted away from the sun. In the southern hemisphere conditions are exactly reversed. Since nights are long and days are short in the setup, the seasons would be winter in the northern hemisphere—the date about December 21.

Observe that a little less than half of the globe is lighted and that the shadow line falls just south of the Arctic Circle. Exactly half would be lighted and the light would fall exactly at the Arctic Circle if it were not for the fact that the globe is much too large for the size of the "sun." See Figure 23, page 42.

At this point it would be well to calculate the size of lamp needed to be in the proper proportion to the globe. In the case of a 16-inch globe the "sun" would need to be 145 feet across and about three miles away.

Notice also that no matter how the globe is rotated, the North Pole is always in darkness and the South Pole in light.

Now slide the globe one-quarter way around the chalked circle, keeping the light always on it and the axis always pointed north. Remember that "north" means toward the north star off in space and not just toward the "north" card in the room.

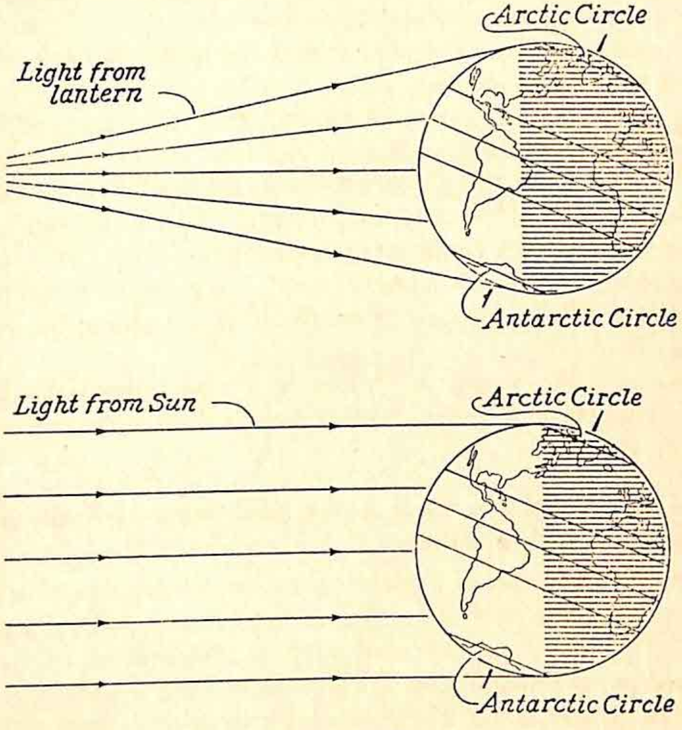

FIGURE 23

Notice that in the new position of the globe both poles are lighted and that the lighted part has increased at the place which has been chosen until day is equal to night, provided the place chosen is in the northern hemisphere. The date is about March 21. Since it is a time of "equal nights" all over the earth, it is called the vernal equinox.

Continue sliding the globe around another quarter circle, still keeping the axis pointed north. It will now be in exactly the opposite condition to what it was on December 21. The whole Arctic

Circle will be lighted and the Antarctic Circle dark. The place chosen will now have its days longer than its nights if it is in the northern hemisphere, and vice versa in the southern hemisphere. The date is about June 21. It is the beginning of summer in the northern hemisphere.

Continue to move the globe another quarter circle. Again day and night are equal all over the earth. Both poles are lighted. It is the autumnal equinox, about September 21.

A further quarter circle move and the globe is back where it started at about December 21 of the next year.

Let everyone have a turn at manipulating the globe and lantern. It might be interesting at each of the four positions to place one end of a pencil on the globe (at the location chosen—in the noon position) and point the other end directly toward the "sun." Notice that in the northern hemisphere north of the Tropic of Cancer at noon the sun is always somewhat south but more so in winter than in summer. The sun is never directly overhead except between the tropics.

Obviously, the longer any place is turned toward the sun the warmer it gets; hence the varying length of day is one factor in seasonal change.

### 3. The rays of the sun shine on the earth more vertically at some seasons than at others

In the exact center of a piece of cardboard the size of a lantern slide cut a square hole about $\frac{3}{16}$ inch on a side, with sharp, clean edges. It is easier to cut a larger hole and reduce its size with gummed paper tape. Set up the lantern and globe as before. Place the slide in the lantern and focus the resulting small square of light on the globe. If the lantern stand is the right height, as suggested on p. 39, and if the lantern is aimed horizontally, the light will strike opposite the center of the globe. This beam of light represents one ray of the sun's light. It may be called the *vertical ray*. Or to put it another way, it is the one ray of all those from the lantern which strikes the curved earth at right angles. Wherever that ray falls on the globe, the sun is directly overhead.

With the earth in the December 21 position the vertical ray at noon should fall on the Tropic of Capricorn. Adjust the lantern until it does. Now have a child carefully slide the globe toward the March 21 position, keeping the vertical ray in the center of whatever part of the globe is facing the lantern and keeping the axis of the globe always turned toward the north. The vertical ray may be seen to move northward until it rests (at March 21) on the equator.

Let the children continue moving the globe, keeping its axis toward the north, until it is in the June 21 position. At this point the vertical ray should rest on the Tropic of Cancer, which is as far north as it ever goes. About June 21 the sun halts its apparent northward movement, seems to stand still, and then starts south. Since the "sun stands still," about June 21 is called the summer solstice. The tropics, then, mark the limits of the northward and southward movement of the sun's vertical ray. Outside these limits the sun is *never* directly overhead.

Continue moving the globe to the September 21 position. The vertical ray again moves back to the equator. Continue to the December 21 position. The vertical ray moves southward to the Tropic of Capricorn and there stands still. It is the winter solstice.

Since the vertical ray is closer to a given place in summer than it is in winter, it seems logical that the rays from the sun are more nearly vertical at that place in summer than in winter. This is so. The next experiment shows what difference it makes.

### 4. The more nearly vertical the sun's rays are at any place, the more energy they deliver to that place

(*a*) Make a chalk mark on the floor. Let a child hold a flashlight exactly one yard from the mark and vertically over it. Shine the flashlight on the mark. Have another child draw a circle with chalk around the spot of light. Now still holding the flashlight one yard from the mark, let the light shine slantingly on the mark. Again draw around the spot of light. The second drawing will be much larger than the first. Since neither the flashlight nor its distance has changed the difference is obviously due to the slant. Although the same amount of light falls on the floor it is "spread thinner" and not so much falls on any one place. In winter the sun's rays fall more slantingly at any one place and therefore the sun's energy is spread thinner on that place.

Because the earth is round the northern and southern portions slant away from the sun just as the floor slanted away from the flashlight, and therefore the northern and southern portions are heated less by the sun than is the equatorial portion.

(*b*) Secure a square of cardboard or bristol board somewhat larger than the globe. For this experiment the lantern will not be needed. Cut out of one side a half circle so that when the cardboard is held closely against the globe, as in Figure 24, it fits snugly. Rule the cardboard into stripes of equal size, and paint alternate stripes so that they are easily distinguishable from across the room. These stripes represent rays of equal intensity. Choose two convenient points on the globe that are in the same longitude, one near the equator and one near the Arctic Circle. Hold the cardboard so that the earth's axis is tilted *toward* the simulated sun's rays (the summer position) and count the number of rays that strike the chosen meridian between the chosen points. Then turn the globe so that the axis is tilted *away* from the rays (winter position). Again count the number of rays falling between the points, and it will be found that only about half as many rays or half as much light strikes the same length of the meridian in winter as in summer.

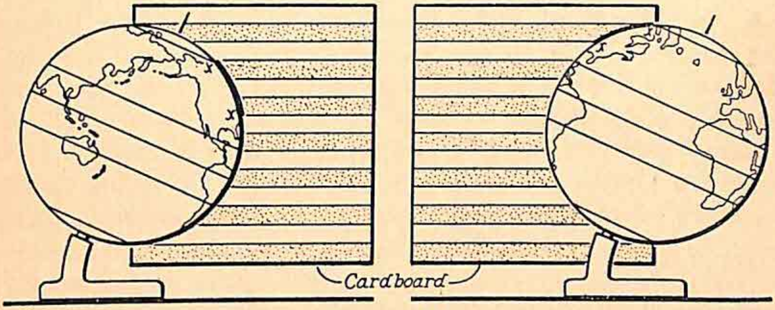

FIGURE 24

(*c*) Fasten two boards, each about 18 inches long, together at right angles as shown in Figure 25, page 46. Cover them with black paper. Against the vertical one hang a chemical thermometer[2] with a long bulb so that the bulb is about 3 inches from the horizontal board. A thermometer with a spherical bulb will not work. Directly opposite the bulb of the thermometer and about 8 inches away from it hang a bare electric light bulb. Use as large a bulb as you can get; a 200-watt one or a photoflood bulb is preferable. On the horizontal board lay another similar thermometer so that the electric light rays fall slantingly on it. Be sure that the bulb of this horizontal thermometer is exactly the same distance from the electric light as the bulb of the vertical thermometer. The diagram given in Figure 25 shows the distances to be measured.

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[2] See footnote, page 29.

Note and record the readings of both thermometers. Turn on the electric light and leave it on for ten minutes. Read both thermometers again. Subtract the first set of readings from the second to determine the rise in temperature of each thermometer. This will indicate that the temperature of the vertical thermometer, on which the light falls squarely, has risen considerably more than the temperature of the horizontal one on which the light falls slantingly. A difference of 10° (using a 200-watt bulb) is not unusual.

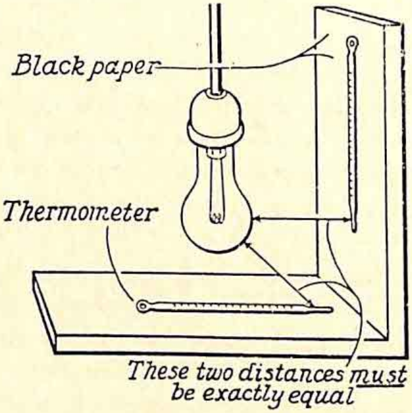

FIGURE 25

(*d*) Secure a piece of etched glass such as is used for handmade lantern slides, or a blank "Slidecraft"[3] lantern slide. With a pen and India ink draw horizontal and vertical lines ⅛ inch apart, thus ruling off the slide into ⅛ inch squares. When this slide is placed in the lantern, each square that is projected contains the same amount of light. Now place the lantern in the center of the chalk circle and focus the pattern of squares on the globe. Repeat Experiment 3 and notice how many squares of light fall on, say, North America at each season. Note also that one square of light covers much more territory near the poles than it does at the equator, and much more ground at the places which are having sunrise and sunset than at the place which is having noon.

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[3] Obtainable from the Slidecraft Co., 257 Audley Street, South Orange, N. J. They come in several sizes; inexpensive.

### 5. The moon revolves about the earth and rotates on its own axis. Eclipses occur when the sun, earth, and moon are in line.

Place the globe on a stool or small table in the center of the room, with a cleared space around it. Place the lantern (or a large flashlight) on a table at the edge of the cleared space. Seat the class outside the cleared space.

Thrust a knitting needle through a ball about the size of a tennis ball. This is the "moon." If the ball is painted with aluminum paint the demonstration shows up better.

Have one of the class stand behind the globe directly opposite the lantern, and look across the top of the globe. This person represents an observer on earth who is to report what he sees. The rest of the class are "out in space," and do not see the same thing. Turn on the lantern and push the lens all the way in. Hold the "moon" between the "earth" and the "sun," but do not let the moon's shadow fall on the earth. The earth observer should not be able to see the moon because the light is directly in his eyes.

Now carry the moon slowly around the globe in a counterclockwise direction. Have someone stationed at the lantern to keep the light on the moon, not on the earth. The earth observer should move so that he is always on the opposite side of the earth from the moon. As the teacher carries the moon around the earth the observer should see first a small sliver of the lighted part, then more and more of the lighted part until when the moon is on the opposite side of the earth from the sun he should see the "full moon." Then he should see less and less of the lighted portion until the moon disappears again. See upper illustration, Figure 26.

Check the fact that the other observers did not see the same thing. Then allow the rest of the class to have turns as observers and manipulators.

The moon rotates as well as revolves, but its rotation takes exactly the same time as its revolution. That is why we always see the same side of the moon. To prove this, temporarily remove the globe and have a person take its place. Let another person represent the moon. Have the "moon-person" go around the "earth-person," always facing him. In order to do this, the "moon-person" must face one side of the room after another, so he is really rotating or turning around in the room while he is traveling around the earth. If he tries to revolve around the earth while always facing the same side of the room, then he must sometimes turn his back on the earth.

Replace the globe. Make a mark on one side of the moon-ball, and prove that in order to keep this mark toward the earth you must rotate the moon as you revolve it.

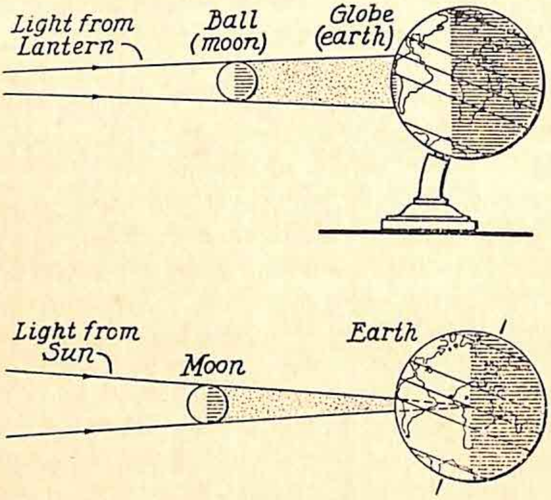

FIGURE 26

Light the lantern again. Notice that whenever the moon gets directly between the "earth" and the "sun" it throws a shadow on the earth. This is an eclipse of the sun. Whenever the earth gets between the moon and the sun there is an eclipse of the moon.

One would expect from this demonstration a solar eclipse every month. But the plane of the moon's orbit is not quite parallel to the plane of the earth's orbit; therefore the earth, sun, and moon do not always line up at the exact time that the moon is on the same side of the earth as the sun. Furthermore, because the moon is smaller than the sun, it casts a very small shadow, and the shadow has a definite length. Actually the moon's shadow is only a very little longer than the distance between the earth and the moon even at the moon's closest approach. Hence the moon must be in exactly the right position before there is a solar eclipse. See lower illustration, Figure 26.

In the demonstration setup natural conditions are not correctly reproduced, because the moon is as large as or larger than the lens of the lantern. The difference between the real and the demonstration case is shown in Figure 26.

The fact that a small object lighted by sunlight casts a shadow of definite length is easily shown by modeling a small "moon-ball" of clay on the end of a knitting needle. Hold this ball in the real sunshine and allow it to cast a shadow on a globe. When the ball is close to the globe it casts a sharp round black shadow, but as the ball is moved away from the globe the shadow soon becomes gray and fuzzy. Scientists call the black shadow the *umbra* and the gray partial shadow the *penumbra.* People in the moon's penumbra see a partial eclipse of the sun.

The moon rises later each day. If the moon were stationary while the earth rotated, it would rise at the same time every night. Actually while the earth is rotating once, the moon is moving on in its path. Hence the earth must turn a little farther each night before a given place gets to a point where people there can see the moon.

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## CHAPTER V

# *Magnetism and Electricity*

Children in the elementary school need to have an understanding of man's use of physical forces. No force has been of more importance in the development of the cultural world as we know it today than electricity. But in a larger sense it has been electrical knowledge which has greatly influenced man's scientific thinking, for all modern theories of the ultimate structure of matter, that is, of everything in the universe, are based on the principle that matter is electrical in structure.

Magnetism and electricity are closely related. In a book of this kind they are separated merely for convenience.

There is a logical structure to this chapter. The first section begins with experiments illustrating the general behavior of magnets, continues with a consideration of why magnets behave as they do, and culminates in a scientific theory of magnetism. Following this a number of simple magnetic devices which children may make are described.

The section on static electricity includes experiences directed toward an understanding of how materials behave when a few electrons are added to or taken away from them. This is brought out in many ways. An attempt has been made to show the connection between the behavior of electrons at rest (static electricity) and the behavior of electrons in motion (current electricity).

Next are given a number of experiences with electrical circuits and wiring, and finally the very important principle that magnetism and electricity are interrelated is illustrated.

## MAGNETISM

### 1. Magnets attract some materials, but not others

The children should try as many different kinds of materials as are available to see which ones are attracted by a magnet.

### 2. The magnet does not have the same attraction over its entire length

Dip a magnet into a dish of nails, tacks, or iron filings. To what parts do many nails cling? What part has little or no attractive power?

### 3. Magnetism can be "borrowed" or induced

Allow a magnet to attract a fairly large nail. Then, with the nail still clinging to the magnet, touch it to other somewhat smaller nails. Is the nail now a magnet? Gently detach the large nail from the magnet. What happens to the small nails? The large nail may retain a small amount of magnetism, called residual magnetism.

### 4. Induced magnetism does not demand direct contact

(*a*) Repeat Experiment 3, but have several thicknesses of paper or a piece of cardboard between the large nail and the magnet. Is the large nail still a magnet? Is it as strong as before? It is better not to use the same nail as was used in Experiment 3 because of the residual magnetism which may remain in it.

(*b*) Cut a piece of wood about 8 inches long, 1 inch wide, and ¾ inch thick. Drive a large nail through one end of it, and sink the head of the nail into the wood. (A nail with a small head will be less likely to split the wood than one with a large head.) Now lay a bar magnet[1] on top of the wood and fasten it on with two rubber bands. It should be near the nail but not touching it. Dip the nail into some little nails and it may be seen that the large nail is magnetized. But, as before, if the bar magnet is taken away, the large nail loses its magnetism and the little ones fall off.

### 5. Lodestones

Lodestones are natural magnets. They are composed of a mineral, magnetite, which contains iron. Weak ones are rather common. Repeat some of the foregoing experiments, especially Experiment 2, using a lodestone instead of an artificial magnet. Like any other magnet, lodestone does not have the same attraction over its entire surface, the attraction is concentrated at poles.

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[1] Bar magnets may be obtained from a scientific supply house for about $1.20 a pair. They may also be found occasionally in toy stores.

### 6. Like magnetic poles repel each other; unlike poles attract each other

Prepare a stirrup of wire by bending a paper clip as shown in the illustration. Place a bar magnet in the stirrup and suspend it by a thread from a horizontal stick. Wait a few minutes for the magnet to come to rest. Approach the north end of the suspended magnet with the north end of another magnet. Repeat, using the south pole of the other magnet. Try all four combinations of poles. Which combinations produce attraction? Which repulsion? Repeat the experiment, using an ordinary piece of iron instead of a magnet. Suppose one had a piece of iron and wished to see if it were a magnet. Why would it be necessary to prove that it *repelled,* not merely *attracted* another magnet? This would be necessary because any piece of iron will attract a magnet or be attracted by a magnet.

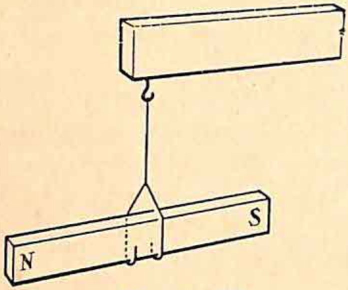

FIGURE 27

Allow the suspended magnet to come to rest. Which way does it point? Why? If it does not point to the north, why not?

### 7. The needle of a compass is a permanent magnet

Using the knowledge of magnetism gained in Experiment 6, prove the above statement. Consider the compass as an unknown piece of iron, and test it with a magnet. If the magnet repels one end of the compass needle and attracts the other, it proves that the compass needle is also a magnet. In working with compasses and magnets, start with the magnet a foot or two away from the compass and approach the compass slowly with the magnet. A compass may be damaged by being brought too close to a strong magnet.

### 8. A magnet may be made from another magnet

Any piece of hard steel such as a knitting or darning needle, a knife blade, a screw driver, or a pair of scissors may easily be magnetized. Select one end of a magnet—it does not matter which end so long as one does not change ends during the operation. Beginning at one end of the piece of steel (a knitting needle is suggested), rub always in the same direction with the same end of the magnet. After about 20 strokes, test the steel for magnetism, using a small compass and being sure to get repulsion as well as attraction. Try to magnetize a nail or a soft iron bar. Soft iron loses its magnetism very quickly, hard steel retains it indefinitely. A nail is quite soft, hence it retains only a little magnetism.

### 9. Heating removes magnetism

Magnetize and test a darning needle. Do not use a knitting needle, as it is too large. Hold the darning needle with pliers, and heat it to redness for a few minutes in a gas flame. Be sure to heat it all over. Let it cool. Test it again for magnetism. The heat softens the steel and allows it to lose most of its magnetism.

### 10. Magnets are surrounded by a magnetic field

The magnetic field is that space within which the influence of a magnet is felt. Obviously, it has no definite boundaries, for a more sensitive detecting instrument would show a larger field than a less sensitive one. This experiment illustrates ways of making part of this field visible and hence more concrete to children.

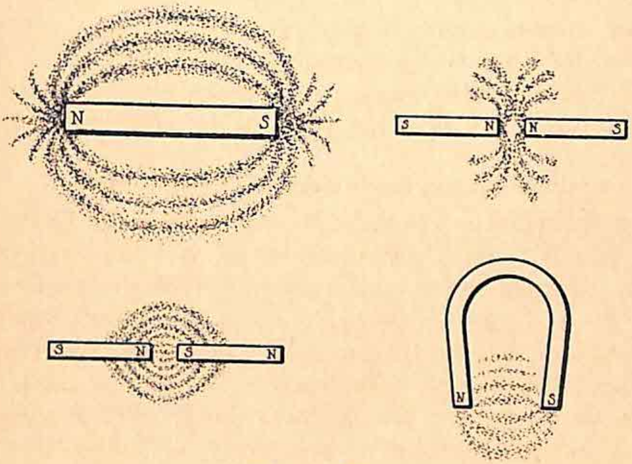

FIGURE 28

Lay two thin strips of wood or two rulers on the table, about 3 or 4 inches apart. In the space between, put a bar magnet. Over the wood and the magnet, lay a piece of stiff paper, glass, or thin cardboard. Hold a shaker of fine iron filings about 3 feet above the table; sprinkle the filings evenly over the paper. Then tap the paper lightly with a pencil. The filings will arrange themselves in lines, called "lines of force." These lines show the direction of the magnetic field. Do not continue tapping too long, as the filings will go to the poles of the magnet and spoil the pattern.

Notice that every line leaves one part of the magnet and runs by a curved path to the corresponding part on the other end.

This experiment may be repeated, using combinations of magnets. Various combinations of poles may be tried. For example, lay two bar magnets in a line with the two north poles an inch apart. Trace the lines of force as before. Then reverse one magnet so as to have unlike poles near each other and again trace the lines of force. Notice that in one case the lines run directly from one pole to the other, while in the other they behave quite differently. Examples are given in Figure 28.

### 11. How to make a permanent diagram of the magnetic field

Prepare a pan of melted paraffin, taking care not to over-heat the paraffin because of danger of fire. Cut some strips of brown wrapping paper a yard or so long and a little narrower than the pan. Holding one end of the strip in each hand, pass it quickly through the paraffin; then hold it by one end until the excess paraffin has dripped off and the waxed paper is cool. Then cut the strip into lengths of about 10 inches. Lay down some magnets as in Experiment 10. On the magnets, lay a piece of glass, and on the glass a piece of the waxed paper, curved side down. Light a gas burner and turn the flame low. Make the design of the magnetic field as before. Lift the waxed paper with the filings on it *straight up* and carry it to the flame. Hold the waxed paper about 6 or 8 inches above the flame, moving it constantly until the wax melts. Carry it away from the flame and hold it until the wax is again cool. There will be a permanent design formed by the filings melted into the wax. An electric stove, if available, is more convenient than the gas burner for melting the wax.

### 12. Magnetism passes through most substances

Fasten a U-magnet[2] to a clamp on a stand, as is shown in

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[2] A rather strong magnet is necessary for this experiment. A suitable one may be obtained from a scientific supply house for about 65 cents.

Figure 29. Tie a thread (not a string) around the base of the stand and tie a paper clip to the thread, as shown. Adjust the magnet so that there is a space of about ¼ inch between it and the paper clip. The clip will remain suspended in mid-air by the force of the magnet. Pass various substances through the space between the clip and the magnet. Materials suggested are glass, paper, rubber, copper, aluminum, zinc, sheet iron (from a "tin" can). The paper clip drops only when the iron is in the space. Magnetism passes through most materials except iron, which absorbs the magnetism.

In what ways do Experiments 4, 10, and 11 show the same thing as Experiment 12?

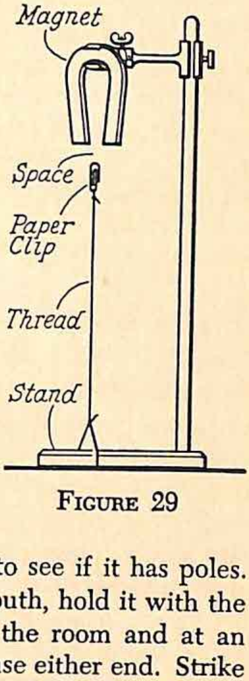

FIGURE 29

### 13. Iron objects in the earth's magnetic field are often magnets

Iron objects which remain motionless for a long time in the earth's magnetic field often become magnetized. With a compass needle test the bottoms and tops of radiators, ring stands, or other iron objects in the room. Do they exhibit polarity; that is, do they have north and south magnetic poles?

Unscrew the rod from a ring stand. Test it to see if it has poles. If one end appears to be north and the other south, hold it with the south end pointing to the northern corner of the room and at an angle of about 45° downward. If it is neutral, use either end. Strike the end of the rod a few vigorous blows with a hammer. Test it again for polarity. Have the poles changed in any way? Explain in terms of the molecular theory. (See Experiment 14.)

### 14. A broken magnet still has two poles—the molecular theory of magnetism

Test a small magnet from the five-and-ten-cent store with a compass, and mark the north and south poles. Take two pairs of pliers and break the magnet in two. It is brittle and breaks easily. Test the pieces. It will be found that the part which was formerly neutral now has poles; that is, there are now two complete magnets. Still keeping track of the polarity, break one of the pieces again.

The little pieces will still be complete magnets. If it were possible to continue breaking the magnet to the final molecules, these would be found to have north and south poles.

The *molecular theory* of magnetism assumes that each molecule of iron is a tiny magnet. In unmagnetized iron, the molecules are arranged helter-skelter. As a result, no part of the iron is any more north or south than any other part. If, however, all (or many) of the north poles are pulled around in one direction, the effect of all the tiny norths (and souths) is added together, and the iron as a whole becomes a magnet.

How does the molecular theory help explain Experiments 2, 3, 8, 9, and 13? In Experiment 8, is it possible now to predict what polarity will be produced in a piece of steel by stroking it with a given pole in a given direction?

Notice that the molecular theory does not attempt to explain why the molecules are magnets. It merely says that if it is assumed that molecules are magnets, certain things about the behavior of magnets can be explained. This illustrates the fact that a scientific theory does not attempt to explain everything.

*Note:* In putting magnets away, they should be placed with *unlike* poles together because the repulsion between like poles would tend to push the molecules out of line. They should never be dropped or struck together violently because the molecules could be jarred out of line. A piece of soft iron (called a "keeper") should always be placed across their ends.

### 15. Children can construct toys and compasses to illustrate principles of magnetism

Children's interest can be aroused and their understanding of magnetism enlarged by constructing a few simple magnetic toys. Other toys may often be found in toy stores. Children should be encouraged to bring to school any they may have. A few simple magnetic toys will be suggested here.

(*a*) Cut a thin slice off a large cork. Cut two strips of waxed paper about ½ inch wide and about 4 inches long. Put them around the cork (Figure 30), fastening them together at each end with a drop of hot wax from a burning candle. Fasten the strips to the cork with hot wax, to give the general shape of a boat. Cut a square sail of paper. Magnetize a large darning needle, and stick it through the paper sail and into the cork. Float the boat in a large pan of water. Use a bar magnet to drive the boat. It will back away from one pole and come toward the other pole.

(*b*) Magnetize a number of small needles. Stick each needle through a small piece of cork, and set them afloat in a big pan. These are to represent fish. The pole may be a pencil or a small stick. Tie a string to one end of it and on the string tie a horseshoe magnet. One end of each fish will be attracted to a particular end of the magnet.

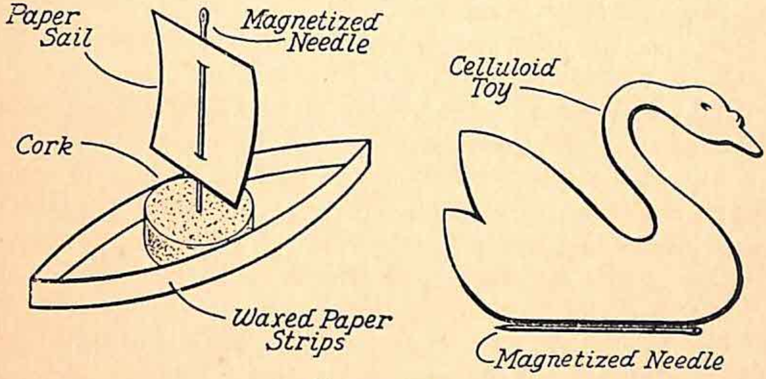

FIGURE 30

(*c*) Another magnetic "fish pond" may be constructed by the children as follows: Cut some shapes of fish from heavy paper, or cut out fish pictures from old magazines. Write a number on each one. Fasten a small paper clip on the nose of each fish. Place the fish in the bottom of a box. Make a fish pole of a stick, a string, and a small magnet. Allow a child to go "fishing" in the pond. He must not be allowed to see his fish until he has caught it. When he has caught a fish, it is the next child's turn. Each child's score is the sum of the numbers on the fishes he has caught.

(*d*) Fasten well-magnetized darning needles to small celluloid bathtub toys or tiny boats. Use glue or hot wax. The toys will respond to a bar magnet held near them. One end of the darning needle will be attracted by the north pole of the magnet, the other end by the south pole.

(*e*) The earliest mariners to use the compass are supposed to have used a lodestone on a float in a dish of water. Place some lodestones in a water tumbler or on a fairly large wooden block and set it afloat in a pottery bowl or in an aquarium. Note if it tends to come to rest in any particular position. Could this experiment be done with a dishpan made of iron? If not, why not? How would you test to see if the pan were really iron?

(*f*) Magnetize a darning needle and stick it through two small bits of cork, one at each end. Float it in a bowl of water. This is another form of floating compass.

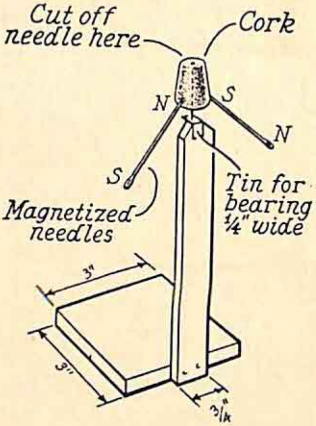

FIGURE 31

(*g*) Prepare a small wooden stand as above. At the top of the upright, tack a small right-angled piece of tin with a dent (*not* a hole) in the top. Thrust a needle through the exact center of a small cork so that the point sticks out of the cork not more than ¼ inch, and cut off the protruding eye end. Magnetize two darning needles in such fashion that the eye of one is north and the eye of the other is south. Thrust them into the sides of the cork opposite each other and at a downward angle as shown. Balance the compass on the upright needle point, which should rest in the dent in the tin. The compass should balance evenly. Have a child test it with a bar magnet to see if the poles are repelled and attracted properly.

(*h*) Another homemade compass may be constructed as follows. This is the most satisfactory of all, if well made, and compares very favorably with purchased demonstration compasses.

Secure a piece of glass tubing about 6 or 8 inches long. Hold it in a gas flame, rotating constantly, until the end has closed. When it is closed and red hot, remove from the flame, hold the open end in the mouth, and blow gently. Reheat and reblow until the inside of the closed end is smooth and spherical. See Figure 32.

With a cork borer, bore a hole straight down through the center of a medium sized (½ inch) cork. Select a cork borer of such a size as to make a hole which will be a tight fit for the glass tube.

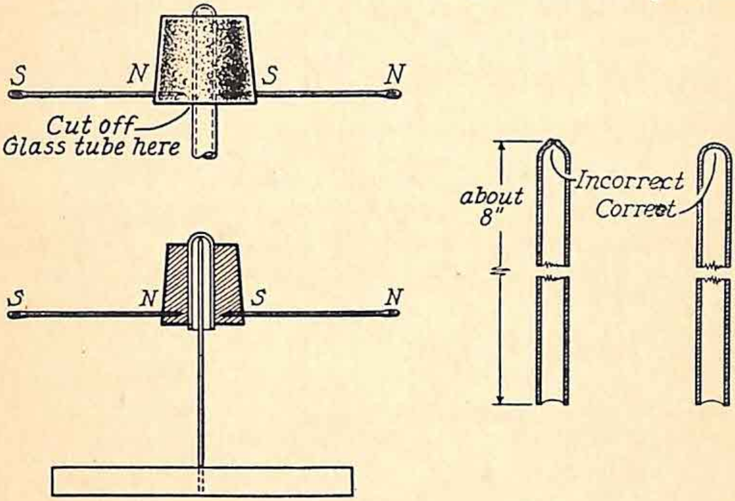

FIGURE 32

When the glass is cool thrust it through the cork until the closed end just protrudes from the large end of the cork. File a notch in the free end of the glass as close to the cork as possible and break off the extra amount of glass. Magnetize two darning needles so that the eye of one is north and the eye of the other is south. Thrust them into opposite sides of the cork, low down.

Prepare a base of wood about 3 inches square. Bore a small hole through the center, taking care to get it straight up and down. Thrust a darning needle through the hole until the eye is concealed in the wood. If the needle is not tight, make it so with a drop of glue.

Place the glass tube, cork, and magnetized needles over the point of the vertical needle and test the compass. It should point accurately north, and should balance with practically no friction.

To complete the compass, dip the north-pointing needle into paint to identify it permanently, and mark the wooden base with the directions North, South, East, and West.

## STATIC ELECTRICITY

Static electricity deals essentially with electricity which is at rest, while current electricity (pp. 64-79) deals with electricity which is more or less free to move. One purpose of this section is to enable children to make the mental connection between the two phases of a study of electricity. A number of experiments are suggested which show that conducting substances are influenced by static electricity provided the electricity is not allowed to escape.

### 16. An electrically charged substance attracts a neutral one. Like charges repel each other, unlike charges attract [3]

(*a*) Secure two balls of pith from the inside of a cornstalk. Watchmakers use pith in cleaning watches, and one may be willing to sell a few small pieces. Hang the two balls by a silk thread from a homemade wooden or glass stand such as is shown in the illustration. Rub a hard rubber rod or a stick of sealing wax with fur or wool. Bring it near the pith balls and note that the balls are at first attracted to the rod because a charged substance attracts a neutral one.

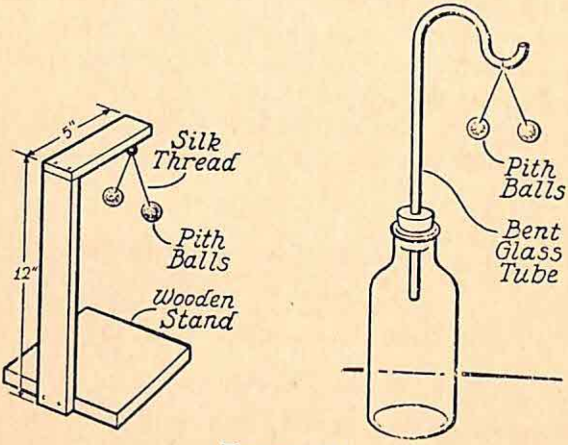

FIGURE 33

Allow the balls to remain attracted to the rod, rolling them about on the rod so that they can acquire the same charge as the rod.

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[3] Static electricity experiments work very poorly in the summer because of the great amount of moisture in the air.

They should presently fly away from the rod and be repelled by it and by each other. They both have the same charge as the rod, and like charges repel each other.

Grasp the balls for a moment in the hand to remove the charges on them, and repeat this experiment, using instead of a rubber or sealing wax rod rubbed with wool or fur a glass rod [4] rubbed with silk. The pith balls should behave just the same, though perhaps not as strongly.

(*b*) Charge pith balls with a rubber or sealing wax rod which has been rubbed with wool or fur. When they are charged, approach them with a glass rod which has been rubbed with silk. Notice that the balls which were repelled by the rubber rod are attracted by the glass rod showing that unlike charges attract each other.

Other materials than pith balls behave similarly. Substitute some of the following for the pith balls and repeat the experiment: Puffed wheat, a small feather, a small scrap of paper, charcoal (carbon) from a burned match, a very small piece of tinfoil or aluminum foil. Notice that metals will respond to static electricity.

(*c*) Secure a small glass plate about 3 × 4 inches. A lantern slide cover glass will do nicely. Cut notches in the small ends of two cork stoppers, and fasten the large ends of the corks to the glass plate with glue in such a way that a hard rubber, sealing wax, glass, or other rod may rest in the notches. Lay a clean watch glass [5] on the table, convex side up. Place the glass plate on the watch glass and the rod in the notches. This makes an arrangement by which a very small force can turn the rod.

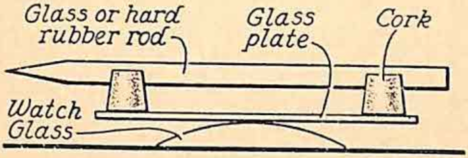

FIGURE 34

Lay an uncharged rod in the notches and approach it with a charged one. Either end of the uncharged rod will swing toward the charged one.

[4] A glass bathroom towel rack may be used.

[5] Watch glasses 3 inches in diameter cost about 50 cents for ten. A watchmaker will probably have them, or they may be bought from a scientific supply house.

(*d*) Hold a rubber or sealing wax rod in its center and rub both ends with wool or fur. Lay it in the holder, taking care not to touch the ends with the hands. Approach first one end and then the other with (1) a charged rubber or sealing wax rod, and (2) a charged glass rod. Notice that if there is attraction or repulsion at one end, there is the same thing at the other end also. This is different from the way two magnets behave, for one end of a magnet is always opposite the other end in polarity.

### 17. The charge on a non-conducting rod is not evenly distributed. It remains where it is placed

Hold one end of a rubber or sealing wax rod in the hand and rub the other end with wool or fur. Lay it in the holder and approach it with another charged rubber or sealing wax rod. The end which was rubbed will be repelled because like charges repel, but the end which was not rubbed will be attracted because a charged body attracts a neutral one. This shows that the charge stayed on the end that was rubbed.

### 18. Metals may be given static electricity charges if the electricity is not permitted to escape. The charge distributes itself on the metal

Lay a metal rod in the holder. If it is available, an aluminum rod about a foot long is suggested because of its lightness. Touch it repeatedly with a charged rubber or sealing wax rod, sliding the rubber rod back and forth across the metal one as though to wipe off the electricity on it. Take care never to touch the metal with the hands. Repeat the charging of the rubber rod and the sliding motion several times. Then test the metal rod to see if the charged rubber rod repels it. Test to see whether the repulsion is at one end or at both ends of the metal rod. Repulsion should be found at both ends, showing that in metals the electricity will move about and spread over the rod.

### 19. Static electricity attracts and repels

(*a*) Into a saucer put some pieces of tissue paper torn up into small pieces, short sections of charcoal from one or two burnt matches, and bits of hair. Hold a glass rod over the saucer as you would a magnet. Nothing happens. Rub the glass very hard for several minutes with a piece of silk cloth, and hold it over the saucer again. Now the materials placed in the saucer will fly to the glass and cling to it. Try the same experiment with a bar of hard rubber, the barrel of a fountain pen, or a comb. The hard rubber bar must be rubbed with a woolen cloth, not with silk.

(*b*) *Sprinkle* a few fine iron filings on the table. Blow up a balloon tightly, rub it with fur, and bring the charged balloon near the filings. The filings jump to the balloon for a short time, then jump away again after they have become charged.

(*c*) Lay a sheet of any metal several inches square (tinfoil will do) on the table. On the metal lay two rulers, parallel and several inches apart. In the space between the rulers, sprinkle some scraps of tissue paper, charcoal, short hair clippings, or bits of pith. Lay a clean glass sheet on the rulers and rub it vigorously with a dry piece of silk. The substances dance up and down between the glass and the metal, taking on a charge as they touch the glass and losing it as they jump to the metal.

(*d*) Hold a piece of dry paper (manila or heavy wrapping paper, preferably) on the wall. Brush it vigorously with a clothes brush and the electrical charge will hold it on the wall. Or brush the paper on a table and then bring it near the wall. It will fly to the wall and stick there. If you are wearing a woolen suit simply hold the paper under your arm and pull it out quickly two or three times.

(*e*) Cut a fringe about 3 inches deep on one edge of a piece of tissue paper. Lay the paper on the table and rub the fringe lengthwise several times with a woolen cloth. The fringe will lie flat on the table because the table is neutral. Pick up the paper and the fringe will immediately stand apart because each part of the fringe has the same charge.

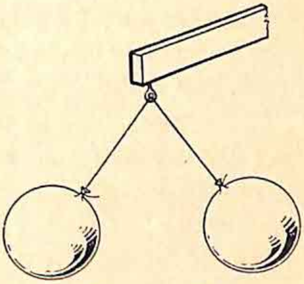

FIGURE 35

(*f*) Blow up two balloons tightly and hang them by strings two feet long from a stick projecting from the wall or held by someone. Have two people rub the balloons with wool or fur, each person rubbing one balloon. Release the balloons and they will repel each other. Notice that they will follow the charged cloth or fur and also any neutral object.

## CURRENT ELECTRICITY

Electricity held more or less at rest on a non-conductor is called static electricity. Electricity which is moving in a conductor is called current electricity.

### 20. Current electricity flows in a closed metallic circuit [6]

Understanding of simple circuits is fundamental to a comprehension of current electricity. The essential point which must be grasped is that electricity *must* have a complete metallic path (called a *circuit*) from one side of the battery through the apparatus to be worked and back to the other side of the battery. If there is only one path, all the electricity which flows must follow that path; if there is a place where the path divides, the electricity divides accordingly. Some goes back to the battery one way, some another. The easier the path, the more electricity flows. Apparatus interposed in a path gives electricity work to do and hence makes that path more difficult. If there is only one path it is called a *series circuit,* because the electricity must pass through a series of things, if there is more than one path it is called a *parallel circuit.* In a given hookup, some parts may be in series and other parts in parallel.

If a certain electrical circuit does not work, given good batteries and other apparatus, it is because of one or both of two reasons: either the path (circuit) is broken somewhere, or one path is so very easy that practically all the electricity is following that path and none is left to work the apparatus. The excessively easy path is called a *short circuit.*

Connect up each of the circuits which are diagrammed in Figure 36.

(*a*) The first diagram represents a very simple electric circuit. Be sure to scrape the insulation from each end of both wires. A flashlight lamp may be used instead of the bell.

(*b*) If it is desired to turn off the bell or lamp without disconnecting the battery it may be done by cutting the wire of the circuit at either point marked X, scraping the insulation off the cut ends and fastening the ends to the two binding screws of a switch or push button.

(*c*) Two (or more) dry cells may be connected as in the second diagram. This will make the lamp burn brighter or the bell ring louder. A wire connects the center terminal of one dry cell to the outside terminal of the next.

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[6] The lamp sockets mentioned in this section may be obtained by cutting up a Christmas-tree string.

(*d*) Two or more lamps may be connected in series as in the third diagram. If both lamps are alike, they will burn with equal brightness, but neither will be as bright as the one lamp. These lamps are said to be connected in series.

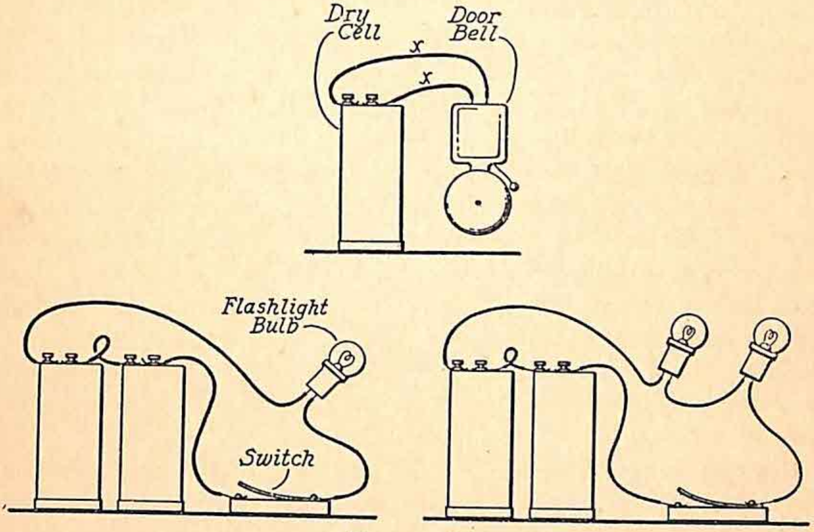

FIGURE 36

Christmas tree strings are sometimes connected in a series. Why do they all go out when one lamp is removed?

Lamps may also be connected in parallel. This is the usual connection in houses. Such connections may also be used for doll houses, streets of toy villages, etc. Each lamp has a path to and from the battery independent of all other lamps. Trace the path of the electricity to each lamp and prove this. How does the brightness of each lamp compare with the lamp in part (*c*) of this experiment? Notice that each lamp is connected directly to the battery.

(*e*) Connect three switches at the three points marked X in the first diagram in Figure 37. What does each switch control? Why?

(*f*) Dry cells as well as lamps may be connected in parallel. They will not be any stronger (have more voltage) than one cell, but they will last longer. This connection is of little use in elementary school work, and is included here mainly for purposes of comparison. (See second diagram.) Disconnect cell A and notice that the brightness of the lamp does not change.

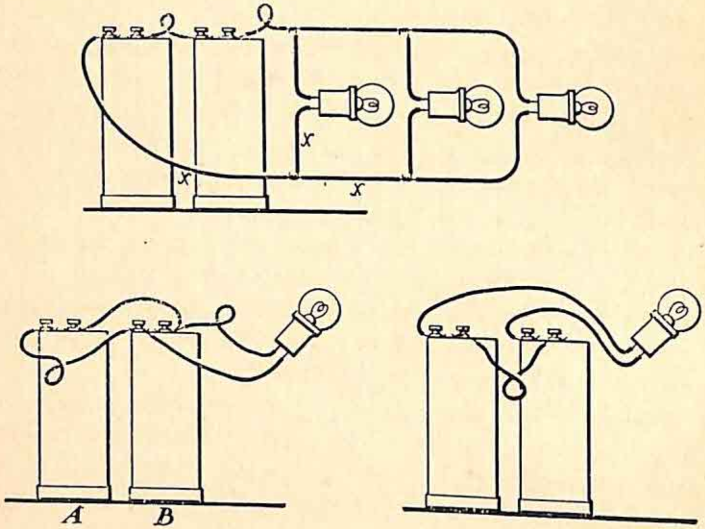

FIGURE 37

Notice the difference between the second circuit and the third circuit shown in Figure 37 which is incorrect and will not work.

Modern first quality dry cells will give surprisingly good service under adverse conditions, but a few rules for their care will prolong

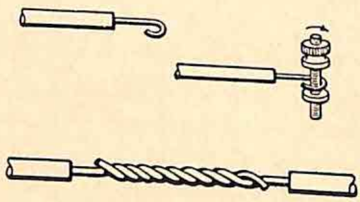

FIGURE 38

their life. If electricity is allowed to go from one side of the battery to the other without having work to do it constitutes a short circuit and the life of the cell will not be long. Therefore, avoid short circuiting the cells. Do not make a practice of testing a cell by putting a piece of metal between the terminals to see if there is a spark, since this will make a short circuit. Use a battery tester; it is cheaper in the end. Never put cells away with wires dangling from them—the loose ends may touch and again short circuit the cell. Do not remove the terminal thumb screws and lay them aside—they frequently disappear.

Insulation of cotton, rubber, or other non-conducting material is placed on wire to keep the electricity where it is wanted and to avoid short circuits if the wires touch. Obviously if one wishes the wires to touch, as in making connections, the insulation must first be removed. In connecting to a dry cell, first remove about one inch of insulation from the wire, and bend the wire to the right in the form of a fishhook. See Figure 38. Loosen the terminal nut or binding post, hook the wire under it, and tighten the nut. The reason for bending the wire to the right is that the nut tightens to the right, and tightening the nut winds the wire tighter around the screw rather than loosens it.

The children should learn how to connect wires properly. In connecting two wires, remove about 1 inch of insulation from the ends, or from the place where the connection is to be made, and twist the bare parts of the wires tightly around each other. Children should be encouraged to make good connections.

Number 22 double cotton covered magnet wire is suggested for use in experiments. It was chosen because the insulation is easily scraped off or unwound, the wire is large enough for most purposes, and yet it is small enough for children to bend it easily. It may be cut with ordinary scissors, or even broken with the hands when necessary.

### 21. Some substances conduct electricity, while others do not

(*a*) Connect up one or two dry cells and a light. Cut one of the wires, so that there is a broken circuit. Touch the two cut ends of the wire to as many substances as it is desired to test. If the lamp lights, the substance is conducting electricity across the gap. What class of substances conducts electricity?

(*b*) A testing device for conductivity may be made from two nails driven a couple of inches apart in a block of wood. Wires are connected to the nails and the substances to be tested placed across the gap between them. If the nails become rusted, they should be shined with sandpaper. Why?

A useful switch or push button can be made from a strip of metal about ¾ inch by 3 inches, a block of wood about 1½ by 4 inches, and three wood screws. Wrap wires around one of the screws which fasten the strip, and also around the screw which the strip touches, before the screws are driven in all the way.

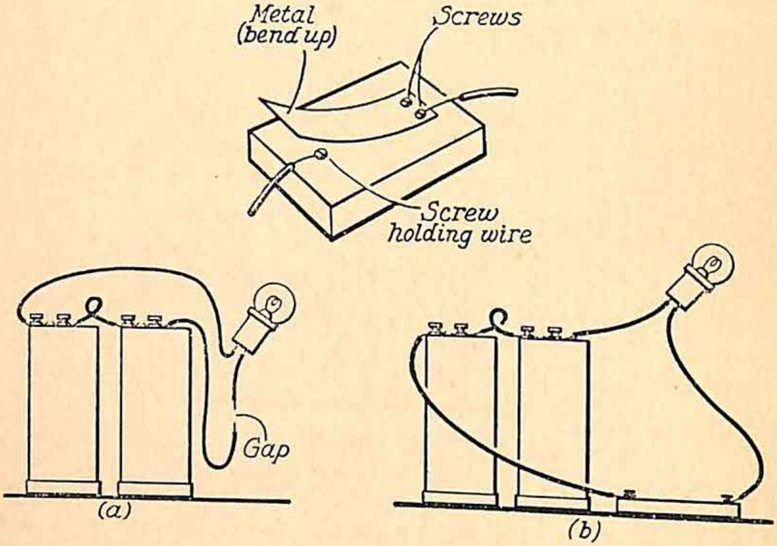

FIGURE 39

### 22. A current of electricity has a heating effect

Unravel a piece of picture wire 6 or 8 inches long, so as to secure one single strand. Cut a piece of copper wire the same length. Twist an end of the copper wire to an end of the picture wire and connect them briefly to a dry cell. Which wire gets hotter? Why? Iron offers more resistance to the passage of the current than does copper. Handle the hot wire with pliers or tweezers. This experiment is very hard on the dry cell. Why?

Examine a toaster or electric heater to see the wires which become hot. These wires are usually made of nichrome, an alloy of nickel, iron, and chromium which has a high resistance. Why?

### 23. Fuses prevent wires from becoming dangerously hot

The more electricity passes through a wire the hotter the wire becomes. If the wires in a house were called upon to carry too much electricity, either because of a short circuit or because too many appliances were being used, the wires might become dangerously hot. To prevent this, a fuse, which is a strip of wire made of metal with a low melting point, is inserted in the circuit. When a dangerous amount of electricity passes through, the fuse gets hot before the wires do. It then melts and breaks the circuit. A fuse is thus a safety device.

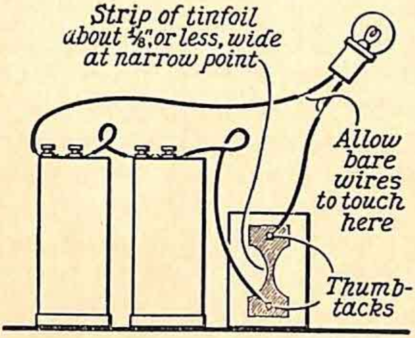

FIGURE 40

(*a*) The device illustrated in Figure 40 shows on a small scale how a fuse works. The narrow part of the tinfoil can carry only a very small amount of electricity, but this small amount is enough to supply the flashlight bulb. When, however, the bulb is short-circuited as the wires touch, a large amount of electricity flows, perhaps enough to heat the wires. But before the wires heat the narrow part of the tinfoil becomes red hot and melts, thereby breaking the circuit and shutting off the electricity.

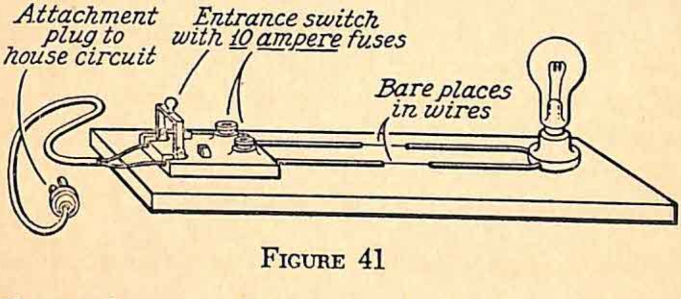

FIGURE 41

(*b*) The teacher may demonstrate the arrangement shown in the illustration (Figure 41) in order to show what happens when a fuse "blows," or melts.

Close the switch and lay a screw driver over the bare places to make a short circuit. Do not use fuses of capacity larger than 10 amperes, as in that case the main fuses of the house might blow instead of those in the apparatus. No harm would be done, but inconvenience would result.

### 24. A current of electricity has a magnetic effect (Oersted's experiment)

Arrange a block of wood, a piece of wire, a switch, a dry cell, and a compass as shown. Be sure the wire points nearly north and south, and that there are no magnets near. Close the switch. What does the compass needle do? Interchange the wires to the dry cell and repeat the experiment. Which way does the compass needle now move? The experiment is also very hard on dry cells, as it constitutes a direct short circuit across them.

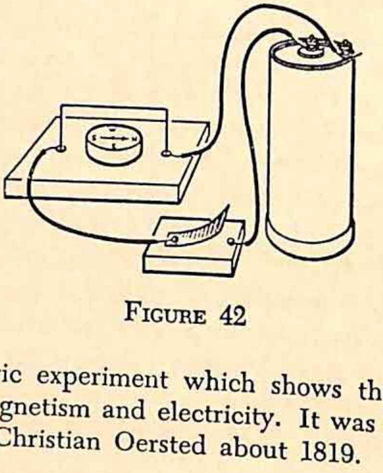

FIGURE 42

This is a historic experiment which shows that a relationship exists between magnetism and electricity. It was accidentally performed by Hans Christian Oersted about 1819.

### 25. A current of electricity may be used to produce magnetism

Wind neatly two or three layers of wire on a large spike or a bolt. Only one layer of wire is shown in Figure 43, but as much wire as can be wound on the bolt should be used. Connect the ends of the wire through a switch to a dry cell. Close the switch and try to pick up some nails or other iron objects. Holding the nails with the magnet, open the switch. What happens? Test the electromagnet with a compass needle to find which end is the north pole. Interchange the wires to the dry cell and test again.

The position of the north pole depends on which way the current is flowing, thus the polarity may easily be controlled.

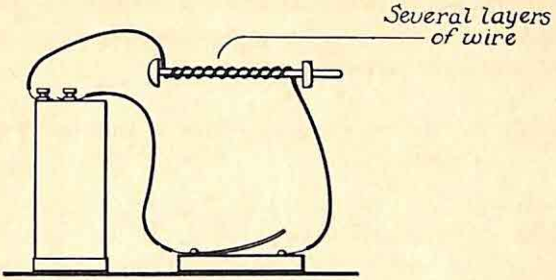

FIGURE 43

### 26. Permanent magnets may be made by a current of electricity acting on a piece of hard steel

Use a steel knitting needle or a pair of scissors in place of the bolt or spike in Experiment 25. The bolt or spike was made of soft iron, and it lost its magnetism as soon as the current was turned off, whereas the hard steel of the knitting needle or the scissors will retain its magnetism indefinitely. The effect is the same as stroking the steel with a permanent magnet. Commercial permanent magnets are made in this way.

### 27. The telegraph uses electromagnets

The telegraph is a means of closing a circuit at one locality and causing an electromagnet located at another place to attract a piece of iron, making a sound. Closing the circuit for long or short intervals conveys a message by a prearranged code of sounds. Figure 44, page 72, shows the principle of the telegraph.[7]

[7] The "ring stand" shown in this illustration is one of the most fundamental pieces of laboratory apparatus because of its versatility as a support. However, as suggested in numerous places in this book, a substitute can often be contrived out of wood.

It is suggested that each school be provided with the following supports and accessories. They may easily be made to serve a number of classrooms:

| | | |
|---|---|---|
| 3 | Ring stand supports @ about........ | $.40 |
| 1 | 2-inch ring with clamp @ about...... | .19 |
| 3 | 4-inch rings with clamps @ about .... | .21 |
| 1 | 5-inch ring with clamp @ about...... | .23 |
| 3 | Burette clamps @ about........... | .30 |

With these at her disposal a teacher can arrange a support to fit almost any need.

A homemade telegraph set may be constructed as follows: A telegraph *sounder* is the part which contains the electromagnet and makes the sound. The *key* is the part which is tapped to make and break the circuit. For two-way communication two keys and two sounders are needed—one of each for each station. The key is merely a glorified push button. A homemade switch (see page

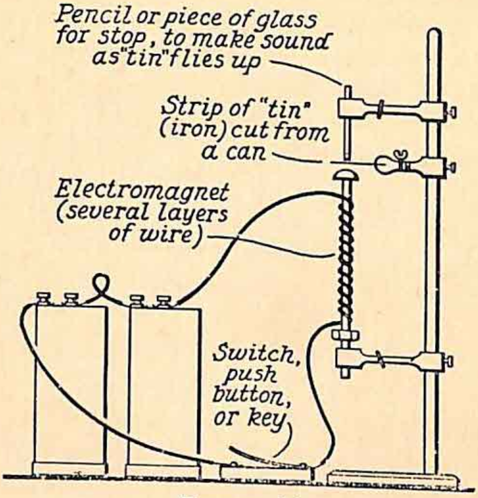
Pencil or piece of glass for stop, to make sound as "tin" flies up
Strip of "tin" (iron) cut from a can
Electromagnet (several layers of wire)
Switch, push button, or key

FIGURE 44

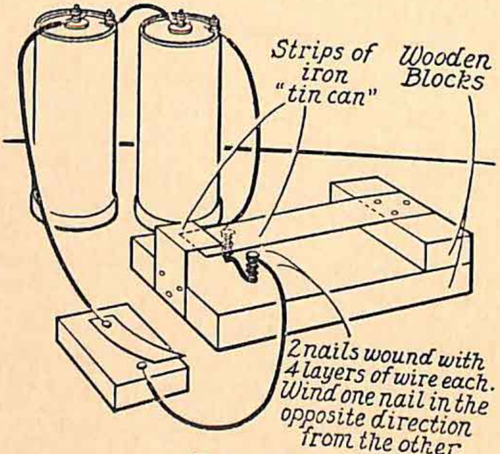
Strips of iron "tin can"
Wooden Blocks
2 nails wound with 4 layers of wire each. Wind one nail in the opposite direction from the other.

FIGURE 45

68) is used as a key. The sounder is made as is shown in Figure 45. Always be sure to cut the wooden blocks so that the grain of the wood runs the long way of the blocks, otherwise they will warp and split. When current flows through the wires around the nails, they become magnetized and attract the iron strip, making a click. When the current is cut off the iron springs back and hits the back stop, making another click. The back stop should be made of the stiffest piece of metal available.

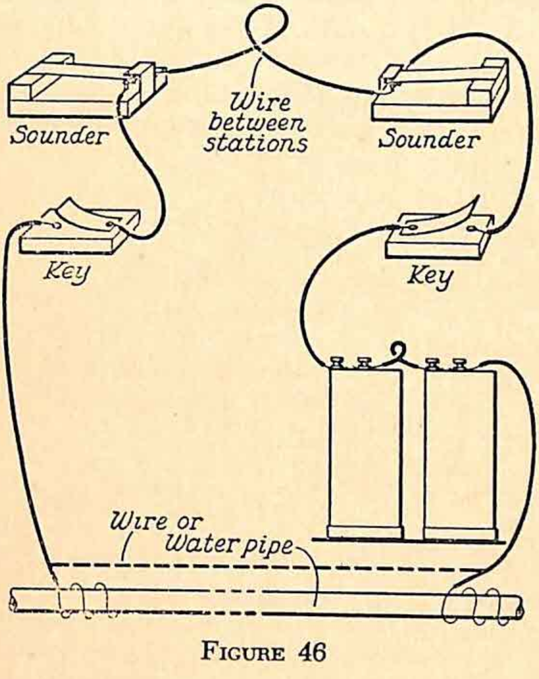

FIGURE 46

The telegraph line may be wired as shown above, from one room to another.

For long distances, connect to water pipes or other pipes buried in the ground, as shown, so as to save wire. Between classrooms use the wire shown in broken line instead of ground (pipe) connections. The "listening" party must always keep his key held down. Why? Real systems have an arrangement which keeps the key closed when not in use. For distances of more than about 20 feet (depending upon the size of the connecting wires), extra batteries may be needed.

### 28. The electric motor and the electric bell—practical applications of the electromagnet

The teacher should demonstrate and explain the electric motor and the electric bell. Examine a few motors and bells to find the electromagnets. (See B. M. Parker, *The Book of Electricity*, pp. 134 and 169. See also G. S. Craig, *Science for the Elementary School Teacher*, p. 491.)

### 29. A homemade galvanoscope

This is an extremely useful and inexpensive instrument for detecting very small amounts of current. It is recommended that every pupil become familiar with it. The compass which is used may be purchased at many sporting goods stores, Boy Scout stores, or opticians.

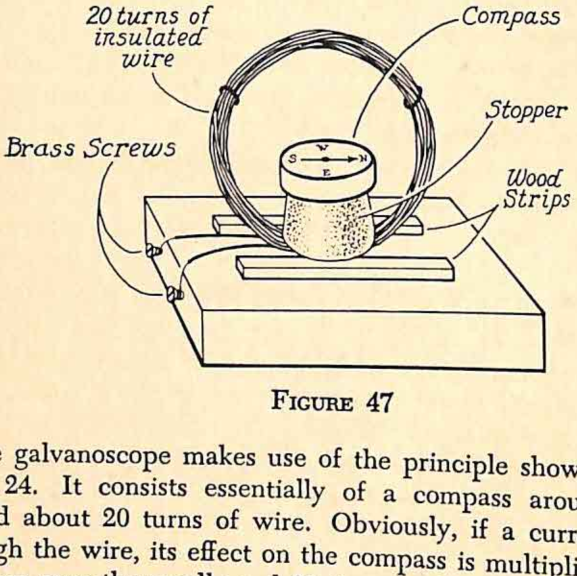

FIGURE 47

The galvanoscope makes use of the principle shown by Experiment 24. It consists essentially of a compass around which is wound about 20 turns of wire. Obviously, if a current is passed through the wire, its effect on the compass is multiplied 40 times—20 times over the needle and 20 times under it. The galvanoscope may be made as in the illustration. It is suggested that the coil be wound on a water tumbler, slipped off, and tied in several places with thread. The rest of the galvanoscope may be held together with glue, as nails may affect the compass needle. See Figure 47.

Connect the galvanoscope to any source of current (e.g., a dry cell) to test it. In use, the coil should be placed in a north-south position. As the electricity passes over and under the compass needle, it causes the needle to turn to one side or the other. A very small current is sufficient to move the needle if other magnets or pieces of iron are kept at a distance. The most important use suggested in this book for the galvanoscope will be in Experiments 30 and 34, where the galvanoscope replaces an expensive galvanometer. Incidentally, the principle of operation of the galvanoscope is the same as many sensitive electrical indicating instruments of the so-called D'Arsonval type, except that in the D'Arsonval instrument the magnet is fixed and the coil does the moving.[8]

### 30. Electricity may be made from chemicals

(*a*) A lemon cell. Prepare two strips, one each of copper and of zinc, about ½ inch wide and 2 inches long. Polish them with sandpaper. Cut two slits in a lemon and insert the strips, taking care that they do not touch. Attach wires to the strips and run them to the galvanoscope. If the lemon cell does not develop enough current to move the needle, try touching the wires to the terminals of a telephone receiver. A click as the wires touch indicates that the cell is producing current.

Collect the juice from several lemons in a small vial. Immerse the copper and zinc strips in the juice and attach the wires to the galvanoscope. There should now be a very distinct movement of the needle.

(*b*) The wet or voltaic cell. Cells of this type were among the first to be used.

The teacher should prepare a solution of sulphuric acid by adding one part of acid to eight parts of water. *NEVER add water to acid;* always acid to water. If any of the acid or the solution is spilled on hands or clothes, wash off immediately with plenty of cold water and apply baking or washing soda.

Cut a strip of copper and one of zinc 1 by 4 inches, and polish them with sandpaper. Attach wires to them by turning over a corner of the strips. Bend the strips so as to hook over a water tumbler. Attach the other ends of the wires to an electric bell, and immerse the strips in the acid solution. The bell may or may not ring. If it does not, add 1 teaspoon of either copper sulphate or potassium bichromate to the solution and stir well with a glass rod. Notice the greatly increased chemical action and the louder ringing of the bell. Observe that the zinc is being eaten away quite rapidly.

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[8] See Robert Stollberg, *Suggestions for Teaching Selected Material from the Field of Electricity*, particularly pp. 49 and 80-85. Bureau of Publications, Teachers College, Columbia University, 1941.

After performing this experiment, wash off the parts of the cell and your hands with cold water. Throw the solution in the sink and wash down with water.

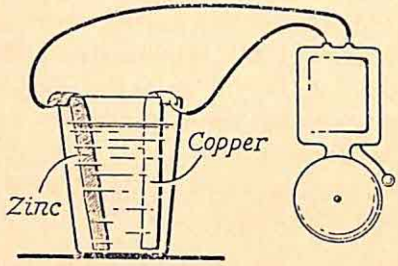


FIGURE 48

(*c*) The dry cell. Cut up an old dry cell, using a can opener or a hammer and cold chisel. Examine it carefully. Notice zinc, blotting paper, black paste, and carbon pole. Is the dry cell really dry inside?

### 31. Electricity from chemical change; chemical change from electricity—the storage cell

Prepare another solution of sulphuric acid. Instead of using copper and zinc strips, this time use strips of lead polished with sandpaper.

Immerse the strips, taking care that they do not touch, and connect them to four dry cells in series. Leave them connected for about five minutes, noting any change in the appearance of the lead strips, formation of bubbles, etc., which give evidence of chemical action.

Disconnect the dry cells and connect in their place an electric bell. The bell should ring. How long will it ring?

This cycle of operations may be repeated indefinitely. When the dry cells are connected electricity is being used to bring about chemical change (i.e., converting electricity into chemical energy); when the bell is connected chemical change is being used to produce an electric current (i.e., converting chemical energy into electrical energy).

### 32. Chemical change from electricity—electroplating

The teacher should prepare a solution by dropping about 4 teaspoons of copper sulphate into a pint of hot tap water. Stir well. Add about a teaspoon of sulphuric acid. Attach a strip of copper to a wire. Fasten the wire to the positive (center) terminal of *one* dry cell and immerse the copper strip in the solution. Make a little holder of copper wire to hold a nickel, dime, or quarter. Attach this wire to the negative (outside) terminal of the dry cell, and immerse the coin in the solution for a few minutes, then remove and examine it. It will be copper-plated. To remove the copper, simply reverse the wires at the dry cell. The copper is always put *on* the negative side and *off* the positive side. Any other metal object (e.g., a spoon) may be used if it is not iron. Iron will not plate in this manner.

### 33. Impure water is a conductor of electricity

Connect two clean metal strips, four dry cells, and a lamp, as shown. (The zinc and copper strips from Experiment 31 may be used or any other available metal strips.) Take care that the strips do not touch. Fill the glass with water from the faucet. The lamp probably will not light. Drop in table salt and watch the lamp.

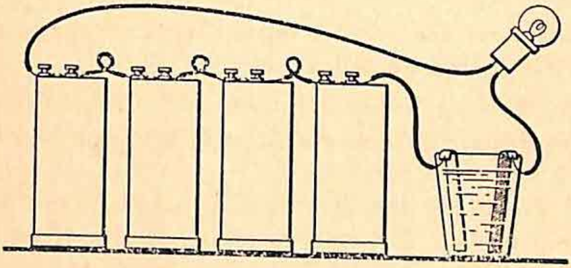


FIGURE 49

Actually, if a strong enough source of current were used, it would be possible to prove that faucet water is also a conductor of electricity, for it is always impure, especially when used for bathing. Why is it dangerous to touch a lamp socket while bathing?

### 34. Electricity from motion—generators

Practically all the electricity which we use to do our work is derived from the energy of motion, for mechanical motion can be produced by any sort of engine, water wheel, etc.

(*a*) Make a coil of about 20 or 30 turns around the bottom of a water tumbler. Slip the coil off and tie it with thread. To its ends, attach wires about 6 feet long. Connect the free ends of the wires to the galvanoscope.

Have someone hold the galvanoscope in a north-south position. Get as far away from it as the wires will allow, holding the coil in one hand and a U-magnet in the other. Holding the magnet motionless, slip the coil quickly over one pole of the magnet. What did the galvanoscope do? Quickly remove the coil. What does the galvanoscope do now? Pass the coil quickly back and forth over the pole, and note what the needle does. Why does one need to hold the magnet still with this setup? Why use such long wires? Does the compass needle indicate any current when the coil is still? What was the source of the electricity which moved the compass needle—the magnet or the movement of the arm?

(*b*) Examine the generator of a toy steam power plant, or a hand-cranked generator. Generators are machines for moving coils of wire with respect to magnetic fields. *Whenever a coil of wire is moved with respect to a magnetic field, a current is generated,* provided there is a circuit in which the current may flow. Direct the pupils to find the coils of wire and the magnets, and to notice how they are moved.

### 35. Transformers. Alternating current

When the switch was closed in Experiment 25 and current was sent through the electromagnet, the electromagnet changed from an object which had no magnetic field to an object having a strong one. In the short time that this was happening, the magnetic field was of course changing or building up. When the switch was opened, a reverse change took place as the field collapsed. Hence a changing field may be secured from an electromagnet without moving it; and if a coil of wire is placed in the changing field, an electric current ought to be produced.

Set up an electromagnet as in Experiment 25. Place the coil of wire from Experiment 34 around it, with the coil connected to the galvanoscope. Close the switch. What happens to the compass needle? Open the switch. What happens now?

The current which was made in Experiment 34 was an alternating current, that is, it flowed alternately in one direction and then in another. If such a current is fed into the electromagnet, of course the magnetic field produced would be changing, and a current would be produced (*induced* is the word) in the coil. The electromagnet and coil constitute a *transformer*.

The advantage of a transformer is that it can change a low voltage to a high voltage or vice versa, without any moving parts. Low voltage is very expensive to send for any considerable distance, while high voltage is dangerous to use. Transformers, therefore, are used to "step up" the voltage until it is economical to transmit, and then are used at the other end of the line to step it down again until it is safe to use. Because transformers work only on alternating current, that is the form of current that is in general use today.

## CHAPTER VI

# *Heat, Light, and Sound*

Heat, light, and sound are manifestations of important physical forces. From birth a child begins to have experiences with them. The fact that a hot stove burns one's fingers, the sounds of nature, and the colors of the surroundings are as truly experiences with these physical forces as the most elaborate experiment. When a child learns that one wears heavy clothes in winter and light ones in summer he has learned to deal with heat phenomena. His first whistle or his first piano lesson teach him something about sound. When he acquires a magnifying glass and examines everything in sight he is making use of the important scientific principle that light rays may be bent or refracted.

This chapter is an attempt to give a broad background of understanding rather than the more specialized one which is appropriate to a later time in the child's life. The experiments included represent a selection from a much larger number of possible activities. Some of them are not proposed as being on a child's level, but rather as scientific background for the teacher.

## HEAT

### 1. Things expand when heated

In general, things tend to take up more room when they are heated over any considerable range of temperature. There are occasional exceptions to this rule. For instance, water contracts slightly as it is warmed from 32° F. to 39° F.

(*a*) Air expands when heated. Experiment 7, page 25, in the chapter on The Atmosphere shows this.

(*b*) Water expands when heated. Secure a bottle and a one-hole stopper to fit it. See Figure 50. Insert a piece of glass tubing a foot or two long into the hole, but do not have the glass tube protruding into the bottle from the small end of the stopper. This is to avoid trapping air when the bottle is filled. Fill the bottle to the brim with colored water and insert the stopper with its tube tightly into the bottle. Water will rise in the tube. Note or mark the place to which it rises. Place the bottle in a cool place and note whether the water in the tube rises or falls; then place the bottle in a warm place and similarly note the position of the water. A crude thermometer has been made which measures temperature by the expansion and contraction of water.

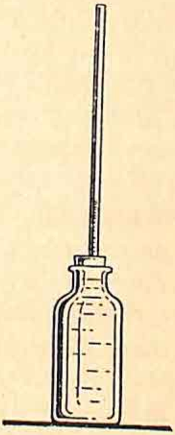
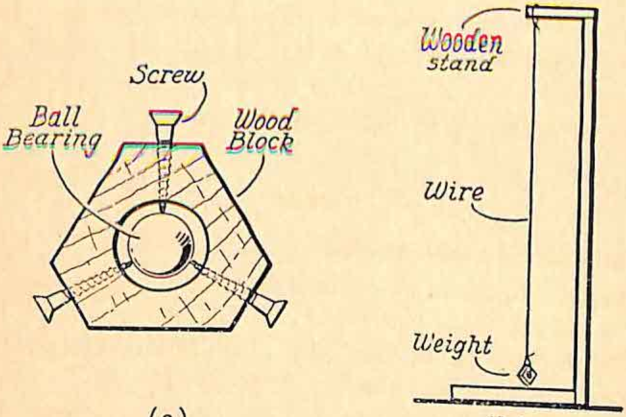


Figure 50

If a Pyrex chemical flask or nursing bottle can be obtained this experiment can be done in a few minutes by heating the flask with a flame. Take care not to boil the water.

(*c*) Solids expand when heated. Secure a fairly large steel ball bearing (½ inch or so in diameter). Cut from a board a piece of wood about 2 inches square. Bore a hole in the wood through which the ball can pass easily. At three equidistant points around the circumference of the hole drive screws so that the points of the screws protrude into the hole far enough to allow the ball barely to pass through, as shown in Figure 51(a). Holding the ball with pliers, heat it well in a flame. It should be found that the ball will no longer pass through the hole. If a ball-and-ring appa-



(a) (b)

Figure 51

ratus[1] is available, it will be found somewhat more convenient to use it.

Obtain a couple of feet of fairly heavy (No. 12 or No. 14) copper wire. Iron wire will also do. Fasten a weight of about one-half pound, such as a scale weight or a good-sized fishing sinker to one end of the wire. Make a wide loop in the other end of the wire, and hang the pendulum so formed from a support. Adjust the support of the pendulum until the weight barely clears the base of the stand. Set the pendulum swinging and heat the wire with a flame along its whole length. If the weight is close enough to the base at the start it should soon touch it as the heat lengthens the wire. This will stop the pendulum. Allow the wire to cool and the pendulum will again swing freely. For this experiment to work well the wire should be carefully straightened. See Figure 51(b).

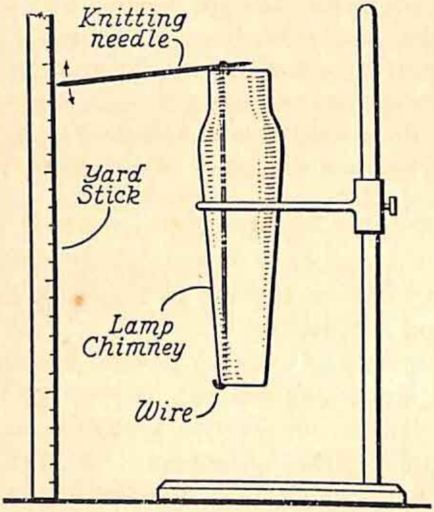


FIGURE 52

Support a lamp chimney with a clamp and stand as is shown in Figure 52. Bend a hook on each end of a piece of heavy wire (iron or copper), so that the bottom hook catches the bottom of the chimney and the top hook holds a knitting needle which rests on the top of the chimney. The knitting needle acts as a pointer which moves as the wire lengthens or shortens. Heat the wire by means of a candle, alcohol flame, or gas burner, and notice the movement of the pointer.

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[1] A ball-and-ring apparatus may be borrowed from the high school, or better still bought for about $1.00 from a scientific supply house.

### 2. Different substances expand in varying amounts when heated

Examine a "compound bar" apparatus.[2] Notice that one side of the bar is made of steel and the other side of brass, and that the two sides are firmly fastened together. Heat the bar and observe that it bends with the brass side on the outside of the curve. Repeat several times to prove that this action is not accidental.

The explanation of the bending of the bar is that brass expands more than steel, and hence forces the bar into a curve with the brass in the longer outside position.

The principle of the compound bar is used in thermostats, oven heat regulators, etc. A thermostat such as is used in home heating systems has a compound bar arranged so that when the room becomes too hot or too cold, the bar bends and closes an electric circuit which starts an electric motor. This motor adjusts the furnace to give more or less heat as required. The compound bar may also be arranged to ring an alarm bell, turn the heat in an incubator off or on, move a needle on a dial, as in some types of thermometers, etc.

### 3. Expansion induced by heat causes water to circulate

Prepare in advance some water-soaked sawdust by placing a quantity of sawdust in a bottle of colored water and setting it aside for a week or two.

Put about 2 inches of water in a wide glass dish which can be placed over a flame. A metal pan may be used if no such glass dish is available. Put one or two spoonfuls of sawdust into the water and apply heat to the bottom of the dish or pan as far to one side or one end as possible. The sawdust moves as the water heats. Soon a vigorous circulation should be seen, with the water rising over the heat and descending in the cooler parts.

When water is heated it expands and takes up more room. This "lighter-for-its-size" water is forced up by the heavier, denser water, which moves in to take its place. This is the principle utilized by most domestic heating systems. It also partly explains the currents of water in the oceans, and by substituting the word "air" for "water," it explains circulation of air on the earth or in the room.

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[2] A "compound bar" apparatus may be purchased from a scientific supply house for about 50 cents.

### 4. Things conduct heat; heat travels along substances

(*a*) Prepare 8 to 10 balls of beeswax. Each ball should be about ¼ inch in diameter. Secure a copper rod a foot to 18 inches long. Support it by one end so that it slants downward slightly. This may be done by putting the end in a rubber stopper and clamping the stopper on a ring stand, or a wooden support may be made for the rod.

Stick a beeswax ball about 1½ inches from the free end of the rod, and the remaining balls at 1½ inch intervals along it.

Place a flame under the free end of the rod, noticing the exact time this is done. As the heat reaches each ball, it will melt and drop off. Record the time each ball drops off. Calculate the length of time it takes the heat to travel each 1½ inch interval. Does the heat travel in the rod at a uniform speed?

(*b*) Repeat the experiment, using rods of different metals. How do metals differ in their conductivity? If a conductometer[8] is available, stick a beeswax ball on each of its rods, heat the junction of all the rods in a flame, and notice the order in which the balls drop off.

(*c*) Take two rods, about 6 inches long, one of steel and one of aluminum. Hold one rod in each hand and thrust the other ends in a flame. Which rod first becomes too hot to hold? What is one advantage of aluminum cooking utensils?

(*d*) Place a wooden spoon and a metal spoon of similar size in boiling water. In which handle is the heat first felt? Why do aluminum cooking utensils usually have handles of some material other than aluminum?

### 5. Water and air are poor conductors of heat

(*a*) From a five-and-ten-cent store or other shop, secure one of the souvenirs which have mounted on them small thermometers. Remove the thermometer and place it in a test tube full of cold water. The thermometer should be about half as long as the test tube. Read the temperature of the water; then heat the water in a flame near the *top* of the test tube until the water starts to boil, and read the thermometer again. Usually the temperature of the water at the bottom will rise only a degree or two while the temperature at the top is rising to boiling. This is because water is a poor conductor of heat. How would the experiment differ if the water were heated at the bottom? (See Experiment 3.) This experiment often cracks the test tube.

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[8] A conductometer consists of a group of rods, usually four, of different metals, fastened together at one end, spread fanwise and attached to a wooden handle. One may be secured from a scientific supply house for about 60 cents.

(*b*) Repeat the experiment, using a test tube of air instead of a test tube of water. Be sure to heat the tube at the top. The test tube may be heated nearly to the melting point without greatly raising the temperature of the air near the bottom. We make use of the fact that air is a poor conductor of heat in the kind of clothing we wear in the winter, for we wear a number of layers of woolen clothes. Because of the curliness of its fibers, wool traps and holds the air which we warm with our bodies. The effect of several layers is also to trap air between them. On the other hand, in summer we wear porous clothing, to allow the heated air next to our skin to escape.

### 6. Things absorb and radiate heat to varying extents

(*a*) Take two tin cans which are alike. Gallon cans with flat sides are preferable. Polish one can as bright as possible. Over the other, paste black paper or paint it with dull black paint. Fill both cans with cold water, and measure the temperature of the water with a thermometer. Put the cans in a sunny window, where the sunlight falls equally on each. In about two hours measure the temperature again. What accounts for the difference in temperature between the water in the bright can and that in the black one, since both received equal amounts of sunlight?

(*b*) Repeat the above experiment, but fill both cans with hot water and set them in the shade. Which one cools faster? Which would heat and cool faster—the bright surface of the ocean or the dull surface of the land? (*Note:* there are other factors involved also in the different rate of heating between land and water.) Which would be best—to paint steam radiators with ordinary paint or to gild them? Why are the large storage tanks for gasoline often painted with aluminum paint?

(*c*) Paste a piece of black paper on a window pane on which the sun shines. Feel the paper and the glass near it. Which is warmer? Feel again when the sun is not shining on the window. What is one reason why people wear dark-colored clothes in winter and light-colored ones in summer?

### 7. Some things hold more heat than others

In a shallow cake pan mold a cake of paraffin wax about one-half inch thick. When the wax is hard, invert the pan, rap it smartly, and the cake of wax will fall out. Place the cake on a tripod, ring stand, or other support.

Secure samples as nearly the same size as possible of several kinds of metals and other materials. A collection which includes pieces of brass, copper, iron, aluminum, hard rubber, and wood has been found satisfactory.

Place all the samples together in a dish of water and bring the water to a boil. Turn off the heat and with pliers or forceps quickly lift the samples one at a time from the boiling water and lay them on the wax cake. When they have all cooled, notice which one has melted its way farthest into the wax. That is the one which held the most heat. This experiment is not strictly rigorous as it leaves out of account the difference in the weights of the substances.

Which holds the most heat, a cupful of boiling water or a gallon of boiling water? Which is at the higher temperature? Which would take longer to bring to a boil?

### 8. Work is related to heat. Friction is a source of heat

(*a*) Rub a brass button or a piece of metal against a piece of woolen cloth. Notice that the metal soon becomes hot, and that the harder and faster you rub (that is, the more work you do) the hotter the metal becomes.

(*b*) The teacher may demonstrate the "Boy Scout Fire Drill" for making fire by friction.

There is a direct relation between heat and work. Heat represents the ability to do work; work represents the ability to produce heat; and the two are interchangeable.

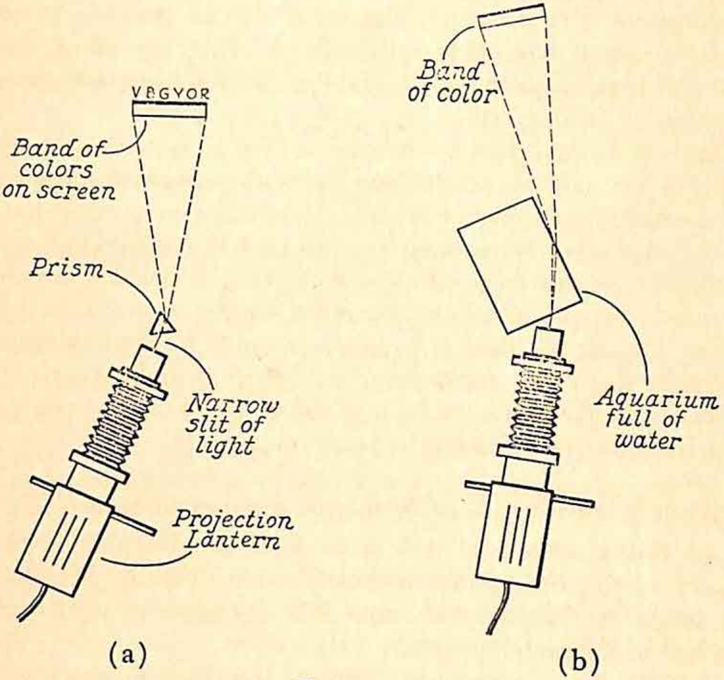
## LIGHT

### 9. Sunlight or white light is a mixture of many colors

Any prism of glass will break sunlight up into its colors. One often sees this play of colors from cut glass objects or from plate glass with beveled edges. However, the following method produces the colors in a way which makes them somewhat easier to study.

Cut a piece of cardboard the size of a lantern slide. In the center of the cardboard, cut a vertical slit about ⅛ inch wide and

1¼ inches long. The edges of this slit should be as straight and clean as possible. Place the cardboard in the projection lantern as you would an ordinary lantern slide, and focus the slit on the screen.



(a) (b)

FIGURE 53

Turn the lantern about 45° to the left or right; then hold a glass prism[4] directly in front of the lens of the lantern so that the slit of light passes through it. Hold the prism so that its length is vertical. See Figure 53(a).

This experiment shows that the "white" light of the lantern bulb is really made up of many different colors, which are separated by the prism. The reason why some objects appear colored is that they absorb some of the colors of sunlight and reflect others. Thus a blue object absorbs all light except blue. Only blue light is reflected to the eye.

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[4] Prisms may often be secured at an optician's store. A suggested prism has a 60° angle between faces and is about 3 inches long. It costs about 60 cents if bought from a scientific supply house.

If a projection lantern is not available, sunlight may be used by making a small hole (perhaps ⅛ inch across) in a dark window shade.

An aquarium filled with clear water makes an excellent substitute for a prism, though its use requires practice. The setup is that shown in Figure 53(b). Even a flashlight may be used as a light source, but with it, it is impossible to get a good *band* of colors.

Sometimes very spectacular colors may be seen when sunlight strikes an aquarium in just the right way.

### 10. Colored objects reflect their own colors and absorb the rest. Color illusions

The following experiment is intended to be performed as a demonstration by the teacher.

Paste a large sheet of bright red mounting paper on a sheet of white Bristol board somewhat larger than the paper. A good way to mount it is by means of small strips of Scotch tape at the corners. Then cut from a large sheet of bright green mounting paper a silhouette of a head or some other object. Mount this green object over the red background, and place the whole arrangement on an easel or hang it on the wall. It is well to cover it with a sheet of paper to conceal it until the time has come to use it.

Next cut out about six pieces of red cellophane the size of a lantern slide and mount the pile of six pieces between two lantern slide cover glasses to form a clear, deep, red lantern slide. Do the same with some blue and some green cellophane. When the red, blue, or green slides are placed in the lantern they throw a strong beam of red, blue, or green light on the colored silhouette.

Completely darken the room, throw a blue light on the silhouette, and remove the cover. The green head should be barely distinguishable from the red background, and the whole should appear almost black. Next throw a green light on the setup. This time the head appears green and the background black. Now throw the red beam, and the head will appear black on a red background. Lastly turn on a white light, and the whole will appear in its true colors.

*Explanation:* (a) Since the red background could reflect only red light and the green head could reflect only green, and since neither red nor green was present in the blue light, both objects appeared black, since they reflected no light at all. (b) The green head reflected the green light, while the red background reflected no light at all, since no red light was present. (c) When the red light was used conditions were just the reverse of (b).

Have some people in bright-colored clothing stand before the class while lights of different colors are thrown on them. Notice the apparent changes of colors.

Some quite startling effects are produced when things are seen in a strong light of a single color. An intense yellow light may be produced by holding some ordinary rock salt or table salt in the flame of a Bunsen burner, using a piece of wire screen cloth as a holder. Objects seen in a dark room illuminated only by this yellow light are seen as either yellow or black. Notice the startling effect on people's complexions as the normal reddish tint becomes invisible.

Stage lighting illusions are based on the changing effect of colored objects illuminated by colored lights.

### 11. The eye may become incapable of seeing certain colors—color fatigue

Use the same red background and green silhouette as before, but arrange it so that it can be whisked away quickly. Place an additional *white* background under it so that when the colored object is removed the white may be seen.

Turn a strong white light from the projection lantern on the colored object, keeping the rest of the room dark. Have the children fix their gaze *steadily* on the illuminated colored object for at least three minutes. Tell them not to allow their gaze to waver; have someone who is not watching keep track of the time. At the end of the time have someone whisk away the colored object, leaving the white background. Let the children gaze at the white background and they should presently see a *red* silhouette in a *green* border. Some children will probably not be able to see this the first time.

The reason for this is that the part of the eye that was seeing red became tired, and unable for a while to see any more red. When the white light from the background struck that part of the eye, it could see only the other colors, but not the red. White light minus red affects the eye as green. In the same way that part of the eye that formerly saw green could now see only white minus green, which appears as red.

Repeat the experiment with different colored objects. In every case the so-called after-image will appear to be of a complementary color. A striking arrangement can be produced by making an American flag, using yellow instead of blue, green instead of red, and black instead of white. After gazing at this for three or four minutes and removing it, the flag will appear in its proper colors.

### 12. Light travels in straight lines

We make use of the principle that light travels in straight lines every time we reach out to grasp something, for a lifetime's experience tells us that the light came straight from the object, and that the object is *there* and not elsewhere. We do the same thing whenever we make a judgment as to the straightness or crookedness of a line, which involves the assumption that the light comes straight to our eyes from the two ends of the line.

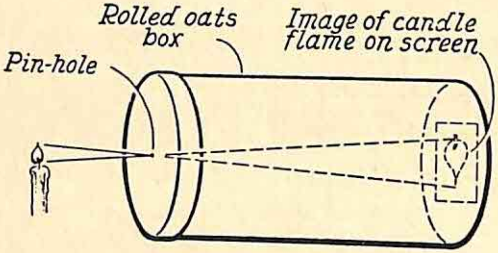

FIGURE 54

Secure a cylindrical cardboard box such as is used for breakfast cereal. In the center of one end cut a hole about the size and shape of a postage stamp. Paste over this hole a thin piece of black paper. Through the exact center of this paper punch a small hole with a needle. In the other end of the box, cut an opening about 3 inches square. Over this paste a piece of thin tissue paper.

Darken the room and hold the end with the pinhole about three or four inches from a burning candle. By looking at the tissue paper end one should see an inverted "image" of the candle flame. Move the box a little closer to or farther away from the flame and notice the difference in the size of the image.

The explanation of this experiment is to be found in the fact that light from the different parts of the candle flame travels in straight lines through the pinhole until it strikes the tissue paper screen. Figure 54 will help to make this clear.

### 13. Light may be bent

Although light normally travels in straight lines, its path may be bent under special circumstances. This fact is of great importance, since it is the basic principle of most optical instruments, including eyeglasses.

(*a*) In the center of a shallow metal dish (e.g., a small pudding pan) place a coin. Place the dish on a table. Have the observers get about six feet or so away and stoop down until they can no longer see the coin. Have an assistant pour water slowly into the pan. As the water level rises, the coin will become visible because the rays of light coming from it are now bent so as to enter the eyes of the observers.

(*b*) Notice that a stick partly immersed in water appears bent because the light coming from the end of the stick which is in the water is bent as it comes to the eye.

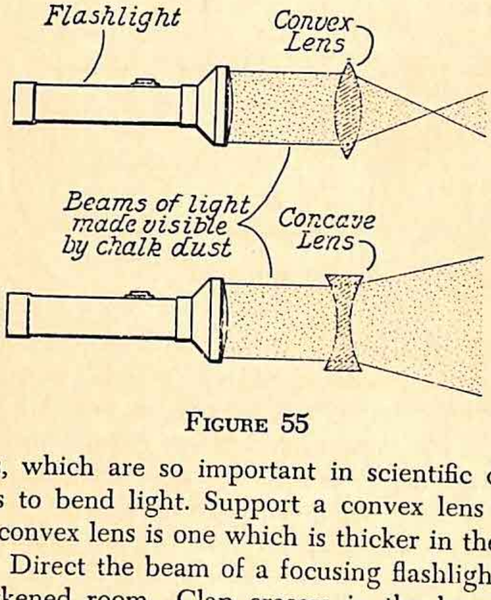

FIGURE 55

(*c*) Lenses, which are so important in scientific discovery, are really devices to bend light. Support a convex lens[5] by a clamp and stand. A convex lens is one which is thicker in the middle than at the edges. Direct the beam of a focusing flashlight through the lens in a darkened room. Clap erasers in the beam of light on both sides of the lens, so that the chalk dust will make the beam visible. Notice that the light which strikes the lens is bent and brought together at a point on the other side of the lens.

If a concave lens (i.e., one that is thinner in the middle than at the edges) is available, pass light through it in the same way, and note that the light as it leaves the lens diverges instead of coming to a point. See Figure 55.

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[5] Reading glass.

(*d*) Some lenses form "images" which may be made visible. Cameras and telescopes make use of this fact. The drawings in Figure 56 show simple setups for demonstrating the principle of the camera and the telescope. Anyone with a few lenses and a considerable stock of patience can reproduce them.

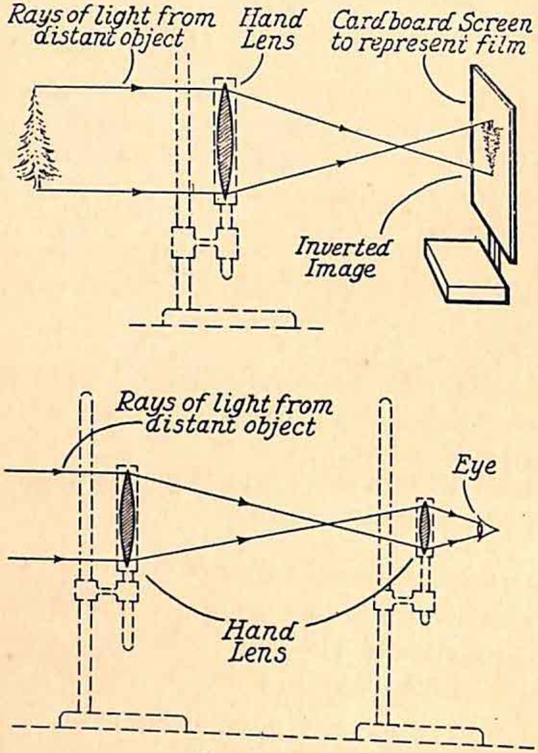
Rays of light from distant object
Hand Lens
Cardboard Screen to represent film
Inverted Image
Rays of light from distant object
Eye
Hand Lens

FIGURE 56

### 14. Light may be reflected

(*a*) Everyone is familiar with his reflection in a shiny surface such as a mirror or a pool of water. The action of a flat mirror may be shown by directing a beam of light from a flashlight on to a mirror in a darkened room and clapping erasers to make the beam visible.

(*b*) Curved mirrors such as are used for shaving or make-up

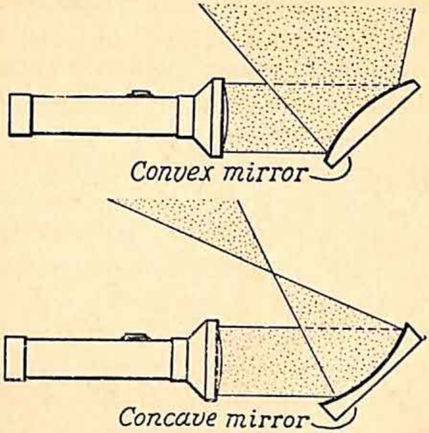

FIGURE 57

mirrors reflect the light differently. Direct a flashlight beam on to a concave ("magnifying") mirror and notice that the light is brought together at a point.

The diagrams in Figure 57 may help to explain further the action of concave mirrors.

### 15. Vision persists for a time in the eye

The eye continues to see an object for a short time after the object is no longer there. This is the principle of motion pictures. Cut a piece of white cardboard about the size of a visiting card.

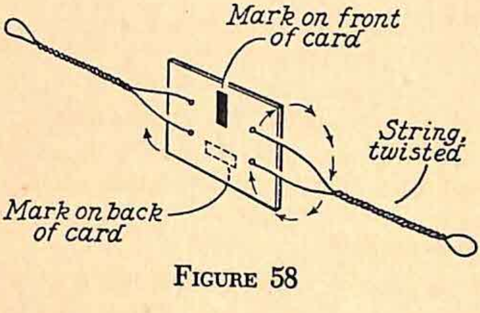

FIGURE 58

Punch four holes in it as shown, and thread a string through the holes so that the card may be whirled rapidly. With India ink make a heavy vertical black line on one end of the card. Make a heavy horizontal line on the other side of the card at the other end. Wind the string and spin the card rapidly by pulling the two loops. One should see the two black marks blending together in the form of a cross. See Figure 58.

### 16. Chemicals impart certain colors to a flame

Prepare a number of strips of wire screening about 1 inch wide and 6 inches long. Hold each strip in a gas flame until it is bright red to burn off any impurities. Set the strips aside on clean paper to cool. Using a strip as a scoop, take up a small quantity of one of the chemicals named in the following list, and hold it in a *clean*, rather low gas flame. If this is done in a darkened room a characteristic color flash will be visible, depending on the chemical used. Under proper conditions *every* element thus imparts its own characteristic color to a flame. By an analysis of the color (much too complicated to be described here) scientists can determine exactly what chemicals are "burning." This form of analysis (called spectrum analysis) can be applied equally well to a distant source of light, such as a star, because one does not need to touch the source of light or even to be close to it. The importance of this experiment to the elementary school child is that it shows that scientists have genuine knowledge when they say that the sun and stars are composed of certain materials. After demonstrating the experiment, the teacher can play a game with the children in which she puts some of the chemicals named into the flame and the children tell by the flame color which one she is using. She then brings out the fact that the children could tell which chemicals were burning without being near them.

The following chemicals have been found effective in the experiment.

| *Chemical* | *Color* | *Element responsible for color* |
|---|---|---|
| Strontium chloride or Strontium nitrate | Bright red | Strontium |
| Lithium chloride | Orange red | Lithium |
| Potassium chloride or Potassium nitrate | Violet | Potassium |
| Copper sulphate | Green | Copper |
| Boric acid | Yellow-green | Boron |
| Powdered zinc | Bright blue | Zinc |
| Sodium chloride (Table salt) | Bright yellow | Sodium |

It is suggested that the sodium chloride be left until last, as the yellow is so strong that it is almost sure to pollute the flame, making it impossible to see the other colors. Solutions of chemicals may be used instead of the dry chemicals if desired. Only a minute quantity is needed. Use each strip of screen only *once* and discard it to avoid carrying chemicals from one test to the next.

## SOUND

### 17. Sound travels

(*a*) Assemble a homemade stethoscope as shown in the illustration, using a small funnel, a glass Y-tube, 3 pieces of rubber tubing, and two earpieces made of glass tubing. Polish the ends of the earpieces by holding them in a gas flame so that there is no danger of cutting the ears. Have some child place the earpieces in his ears and put a funnel over a small watch (e.g., a wristwatch). He can easily hear the watch tick because the air inside the tubes carries the sound.

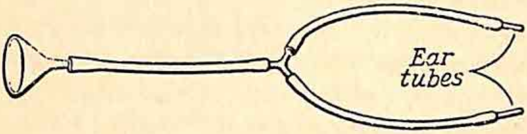

FIGURE 59

The teacher may suggest that when the children are at the beach or swimming pool they put their heads under water while someone clicks two stones together at a short distance. This shows that sound travels in water. Sound also travels in the ground. From their reading the pupils have probably learned that the Indian put his ear to the ground to hear the hoofbeats of a distant horseman.

(*b*) Secure a light wooden stick, about 8 feet long, and an iron rod the same length. Have a pupil stand the length of the stick away, holding a watch. Another child should notice whether he can hear the ticking of the watch, and if so how loud it is. Then the first child should hold the watch against the end of the stick while the other child holds his ear against the other end. The ticking should be louder. This experiment demonstrates that sound travels in solids.

(*c*) The string "telephone" is a device which shows how sound vibrations may be transmitted over a string or wire. Secure 20 or 30 feet of strong, hard-twisted cord and two tin cans such as coffee cans. Cereal boxes will do if cans are not available. Punch a small hole in the center of the bottom of each can. Pass an end of the string through the hole and secure it with a large knot on the inside. Do the same with the other can and the other end of the string. Have a child hold each can, taking care not to touch the bottom. Let the children walk apart until the string is tight between them. Have one child hold his can to his ear, while the other child speaks into his can. Sound will travel over a string for quite surprising distances, provided the string does not touch anything between. This "telephone" will not work around corners. If some lightweight iron or steel wire is used in place of the string, the "telephone" will work over a longer distance.

### 18. Sound is made by something vibrating

This fact may be made clear to the elementary child by bringing to his attention a number of simple illustrations from his immediate environment. He may put his hands on his throat and chest when he is speaking and feel the vibrations. If a stringed instrument, such as a piano, violin, or guitar is available, he may place his hand lightly on the strings of the instrument as it is being played. The teacher may tell him that flutes and other wind instruments have air inside them which is set into vibration as the instrument is played. The child may blow across the mouth of a bottle and hear the tone which is produced by the vibrating air inside the bottle. He may examine a toy xylophone and notice that it has wooden or metal bars which are set into vibration when struck. The following experiments also illustrate the fact that sound is made by something vibrating.

(*a*) Construct a "bull-roarer" by passing a stout cord about 2 feet long through a hole in the bottom of a coffee can and tying a knot in the cord. If a larger can is available, it works even better. Put some rosin on the string, grasp the string firmly in one hand and the can in the other, and draw the hand quickly down the string. It is a good idea to wear a leather glove so as to avoid danger of cutting the hand on the string.

(*b*) Tie an ordinary teaspoon in the middle of a string about 2 feet long. Let a child wrap the ends of the string around his two forefingers and place his forefingers in his ears, allowing the spoon to dangle. Have him swing the spoon so that it strikes the edge of the table, and hear the chime note which is transmitted through the string to his ears.

(*c*) Set a tuning fork[5] into vibration by striking it against something made of rubber (e.g., a rubber heel). Never strike a tuning fork against anything hard, as it will give too many overtones. Always hold a tuning fork by the handle. Dip the prongs of the vibrating fork into a cup of water and notice how the vibration causes the water to splash.

### 19. Pitch depends upon the length, tension, and mass of the material which is vibrating

(*a*) If a guitar is available direct the child to observe that the strings which sound the lowest notes are the heaviest and most massive ones. Tighten or loosen a string and note how the pitch changes. Hold a string firmly against a fret and notice that the shorter the string the higher the pitch.

(*b*) Blow across bottles of different sizes and notice the differences in pitch. Or blow across a bottle when it is empty and again when it is partly full of water.

(*c*) Construct a xylophone out of a number of drinking glasses filled to various depths with water. The greater the depth of water the lower the pitch. It is possible to experiment until an acceptable scale is secured.

### 20. Sounding boards may increase the volume of sounds

Strike a tuning fork and hold it by the handle in the air. Notice how faint a sound it gives. Strike it again and hold the handle against the bottom of a candy box, while a helper holds the box. The sound should be much louder, as the vibrating fork sets the whole box into vibration. This is the principle of the sounding board which is widely used in musical instruments. Try using a table fork instead of a tuning fork.

If several tuning forks which form a chord are available, repeat the above procedure, but have the children hold the other forks, also sounding, against the box. The major chord, C E G C′, is perhaps the simplest. All tuning forks are marked with the number of vibrations they make per second. Notice that if the numbers of vibrations of any two forks which sound well together are set down as a proper fraction and reduced to lowest terms, the resulting fraction is always one in which the terms are small numbers, like $\frac{1}{2}$ or $\frac{2}{3}$. If this relationship does not hold, there is a discord.

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[5] If the music teacher has no tuning forks, they may be purchased from a large music supply house or from a scientific supply house. They cost about $1.25 each. It is suggested that if possible four forks, to give the major chord, C E G C′, be secured.

## LIST OF SCIENTIFIC SUPPLY HOUSES

The following list makes no pretense of being complete. The elementary school teacher should make inquiries at the local high school or a near-by college for the names of any firms which may be closer to her locality than the ones listed. Most firms put out a catalogue which may be secured for the school by someone in authority. It is suggested that the school obtain the catalogue of at least one of the firms here listed, as it will contain much valuable information.

Central Scientific Company
  16 Beale Street, San Francisco 5, Calif.
  1700 Irving Park Road, Chicago 13, Ill.
  79 Amherst Street, Cambridge A Station, Boston, Mass.
  441 Clinton Avenue, Newark 8, N. J.
  347 Madison Avenue, New York 17, N. Y.
Chicago Apparatus Company
  1735-43 North Ashland Avenue, Chicago, Ill.
Eimer and Amend
  633 Greenwich Street, New York, N. Y.
Fisher Scientific Company
  709-19 Forbes Street, Pittsburgh, Pa.
General Biological Supply House
  761-63 East 69th Place, Chicago, Ill.
Cambosco Scientific Company
  37 Antwerp Street, Brighton Station, Boston, Mass.
Ward's Natural Science Establishment, Inc.
  24 Beechwood Station, Rochester 9, N. Y.
W. M. Welch Scientific Company
  1515 Sedgwick Street, Chicago, Ill.

S.C.E.R.T., West
Library
Calcutta
25/3, B. C.